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**Military Operations
Research Society**



**Society for Computer
Simulation International**

Mini-Symposium Report

SIMVAL 99

Making VV&A Effective and Affordable
The Simulation Validation Workshop 1999

26-29 January 1999

Johns Hopkins University Applied Physics Laboratory (JHU/APL)
Laurel, Maryland

Redacted by:

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SIMVAL 99 Annex Presentations — Published separately — (Plenary Keynote Session Briefings, Materials Presented in Working Groups, the Synthesis Group and Thursday Afternoon Outbriefs)

Keynote Presentations

- K-1 "The Future of Technology and VV&A in Warfighting Simulation," CAPT McBride
- K-2 "V&V Technology Review," Col Konwin
- K-3 "Beyond Box Checking: How Can Technology Help Model Building and VV&A?" Dr. Davis

WG1

- D-WG1-1 "M&S Verification Technology: An Overview" by Osman Balci
- D-WG1-2 "M&S Requirements Verification" by Gary Kollmorgen
- D-WG1-3 "M&S Requirements Verification" by Randy Michelsen
- D-WG1-4 "M&S Conceptual Model Verification" by Furman Haddix
- D-WG1-5 "M&S Design Verification" by Delores R. Wallace
- D-WG1-6 "M&S Implementation Verification" by Richard E. Nance
- D-WG1-7 "Overview of Six Major VV&A Processes and Associated Cost Models" by Robert O. Lewis to a combined session for Working Groups 1 and 3

SIMVAL 99 Annex Presentations (continued)

WG2

- D-WG2-1 "Modular Semi-Automated Forces (ModSAF) Experimentation (VV&A, Physical Models, Data)" by John Thomas
- D-WG2-2 "A Construct for the Use of SMEs"

WG3

- D-WG 3-1 "Costing Of Model And Simulation (M&S) Verification, Validation, And Accreditation (VV&A) Within DoD — A Managed (Marginal) Investment Strategy" by Robert Gravitz and Bill Waite
- D-WG 3-2 (same as WG1-7) "Overview of Six Major VV&A Processes and Associated Cost Models" by Robert O. Lewis to a combined session for Working Groups 1 and 3
- D-WG 3-2 "Advanced Distributed Simulation (ADS) Work Breakdown Structure (WBS) AS of 13 Jan 1999" by LTC Cannon

Outbriefs

- Working Group 1 (WG 1)
- Working Group 2 (WG 2)
- Working Group 3 (WG 3)
- Synthesis Group
- SIMVAL 99 Co-Chairs

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The purpose of the Military Operations Research Society (MORS) is to enhance the quality and effectiveness of classified and unclassified military operations research. To accomplish this purpose, the Society provides media for professional exchange and peer criticism among students, theoreticians, practitioners, and users of military operations research. These media consist primarily of the traditional annual MORS Symposia (classified), their published abstracts or proceedings, special mini-symposia, workshops, colloquia and special purpose monographs and other publications. MORS publishes two quarterly periodicals, *PHALANX* and *Military Operations Research*. *PHALANX* is the MORS bulletin and *Military Operations Research* is a referred journal. The forum provided by these media is directed to display the state of the art, to encourage consistent professional quality, to stimulate communication and interaction between practitioners and users, and to foster the interest and development of students of operations research. In performing its function, the Military Operations Research Society does not make or advocate official policy nor does it attempt to influence the formulation of policy. Matters discussed or statements made during the course of its symposia or printed in its publications represent the positions of the individual participants and authors and not of the Society.

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Established in 1952, the Society for Computer Simulation (SCS) International is a non-profit volunteer driven corporation (Simulation Councils, Inc.). SCS International is the multidisciplinary forum dedicated to research, development, and applications of simulation. Members are engineers, scientists, managers, educators, and students from many countries, with organized regional councils in the United States and Canada, the European Economic Community, Pacific Rim, China, and Mexico.

SCS International sponsors several conferences each year providing learning, presentation, and networking opportunities at the forefront of computer-based simulation technologies and applications. Most conference proceedings are published as books.

The monthly journal *SIMULATION* is a refereed publication filled with technical articles, industry news, editorials, an artificial intelligence column, a calendar of events, conference information, and an annual directory of simulation vendors. *TRANSACTIONS OF THE SOCIETY FOR COMPUTER SIMULATION* is a highly refereed, scholarly journal presenting theoretical and practical applications of archival value.

SIMVAL 99 Purpose/Objectives

The Simulation Validation (SIMVAL) 99 Workshop was held at The Johns Hopkins University Applied Physics Laboratory on 26-29 January 1999. This special meeting explored ways to ensure modeling and simulation (M&S) credibility in effective, efficient, and affordable ways. The SIMVAL 99 Workshop was co-sponsored by the Military Operations Research Society (MORS) and the Society for Computer Simulation (SCS) International, and was the fourth in the series of SIMVAL workshops sponsored by MORS. SIMVAL 99 examined current technology supporting verification, validation and accreditation (VV&A) and identified promising areas of possible technology development that could enhance VV&A. Such enhancements could make VV&A more effective for a given level of resources or could allow the same level of VV&A to be achieved with reduced resources. The SIMVAL 99 Workshop focused on three specific areas: (1) verification technology, (2) validation technology and methodology and (3) the impact of technology on VV&A costs. The primary objectives of SIMVAL 99 were to provide a synopsis of the state of the art for VV&A technology and to suggest what should be done to most fully exploit that technology and advance VV&A.

The SIMVAL 99 report has three parts. 1) the report body which contains the findings /observations and recommendations of the workshop as a whole and of the individual groups within the workshop; 2) the appendices of the report which contain supplementary information about the workshop (its attendance, portions of the read-ahead and handout materials, etc.) and 3) an annex which contains the briefings presented at SIMVAL 99 in its opening and closing plenary sessions as well as the briefings presented within the three SIMVAL 99 working groups (most of the briefings are not annotated). All three of these items are available from the MORS Office and from DTIC; the report body and the appendices of the report will be available on the MORS website as the report of SIMVAL 99.

Introduction

Since the late 1980s, MORS has led conceptual development for simulation validation (SIMVAL). Since the last SIMVAL workshop (held in 1994), Verification, Validation and Accreditation (VV&A) have become central themes in Department of Defense (DoD) modeling and simulation. DoD Instruction 5000.61, released in April 1996, set Defense policy guidance for VV&A. The DoD VV&A *Recommended Practices Guide (RPG)*, published in November 1996, provides VV&A guidance within DoD today. Efforts are underway to improve the *RPG* by incorporating lessons learned from those who have followed its guidance. These developments underscore the need for advancing the state-of-the-art in VV&A. Decision makers, program managers, simulation developers, V&V practitioners, VV&A agents, V&V theorists, academic and simulation users are all concerned with the conduct of VV&A. The full scope of current VV&A technology needs to be better understood. Such exposure of VV&A technologies should include not only tools and methodologies for performing V&V, but should also address *costs* associated with conducting VV&A. This process should identify technologies which can increase V&V effectiveness without increasing costs or decrease costs without degrading V&V effectiveness.

VV&A technologies and methodologies have pertinence for those outside DoD as well as for those within the Defense community. Co-sponsorship of the SIMVAL Workshop 99 by the Society for Computer Simulation (SCS) International facilitated involvement in SIMVAL 99 by those outside the Defense community and enlarged the reach of insights from SIMVAL 99 beyond the Defense community. SIMVAL 99 included participants from outside the US (Australia, Germany and the Netherlands) and a few displays/exhibits of V&V technology for some of the tools identified in Appendix F.

The report body begins with findings/observations and recommendations of SIMVAL 99 as a whole. The structure and process used in the conduct of this meeting are then described in the following paragraphs. Synopses from the three Working Groups and the

Synthesis Group are also included. These synopses help to clarify current and future states of VV&A technology. The Working Group (WG) and Synthesis Group (SG) synopses include findings/observations and recommendations, some of which are not identical with overall SIMVAL 99 findings and recommendations. This situation exists because the findings and recommendations of the synopses are from the particular perspective of the group while the overall findings and recommendations balance perspectives from the whole VV&A community. The body of this report ends with a brief conclusion and assorted comments. The following materials are contained in appendices:

- Appendix A:** SIMVAL 99 Terms of Reference (TOR)
- Appendix B:** SIMVAL 99 Agenda
- Appendix C:** SIMVAL 99 Participants (including exhibitors and WG assignments)
- Appendix D:** Identification of SIMVAL 99 presentations (plenary keynote session briefings, materials presented in working groups and the SG and Thursday afternoon outbriefs) – actual briefings are contained in the SIMVAL 99 Annex.
- Appendix E:** Acronyms
- Appendix F:** Read-ahead and Selected Handout Items

Disclaimer of Endorsement: Reference in SIMVAL 99 materials to a specific commercial product, process or service by trade name, trademark, manufacturer or otherwise, does not constitute or imply its endorsement, recommendation, or favoring by the United States Government, by MORS, by SCS International or by any other organization or person. A number of commercial and government tools and software packages are specifically identified in this report. They are mentioned as representative of particular capabilities. The items identified are ones which are known by SIMVAL 99 participants and do not necessarily reflect the totality of such tools and software packages which may be available. Likewise, capabilities asserted for such tools and

software packages are merely the perception of SIMVAL 99 participants and should not be accepted as fact simply on the basis of material in this report.

SIMVAL 99 Findings/Observations and Recommendations

1. Findings & Observations

The modeling and simulation (M&S) community, and the subset of people within it who are concerned with verification, validation and accreditation (VV&A), are so broad and diverse that effective communication is very difficult. Commonly accepted definitions for VV&A terms, such as those provided within the DoD M&S glossary and in formal DoD documents such as DoD directives and the *DoD VV&A Recommended Practices Guide (RPG)*, can be (and are!) interpreted in such different ways by various members of the M&S community that misunderstandings and communication confusion can abound. Lack of a clear articulation of the various perspectives that can be brought to M&S VV&A is part of the cause for this problem. Those working with software architectures have recognized the importance of multiple views for the architecture of a software development to provide a full description of the planned development, such as the *operational, system and technical views* espoused in the DoD Joint Technical Architecture (JTA). M&S VV&A have not matured to the place of having formalized the different perspectives that are equivalent to the different views in software architecture. Also contributing to communication ambiguity in M&S VV&A is the lack of a mathematical level of specificity for most VV&A-related definitions. This problem manifested itself significantly in WG 1 and impeded their progress until it was decided for the group to split and tackle verification issues independently from a global perspective and from a phase-specific verification process perspective. *It is believed that the breadth and depth of potential trouble that such communication difficulties can cause the M&S VV&A community are not fully appreciated by either VV&A practitioners or M&S management.* It appears that the VV&A community is not exploiting existing technology as much as desired. The reasons for this are manifold. First, M&S management and VV&A practitioners as a whole are woefully unaware of existing tools and technologies that could be used to support VV&A. Second, the VV&A community has focused primarily to date on defining terminology and developing methodologies and processes, and

has not given adequate attention to the potential benefits of tools and technologies. Other reasons include the lack of a comprehensive survey of tools and technologies available to support the education of the VV&A community or the use of these resources in DoD and elsewhere. No central repository exists to document VV&A tool use or to serve as a resource for future applications of VV&A tools and technologies. Consequently, resources to support VV&A tool use are not identified routinely as part of M&S lifecycle planning. Even when tools are used, their use is often ad hoc and not repeated consistently from one M&S project to the next.

It appears that advancement in computational capabilities and software engineering are proceeding more rapidly than comparable advances in M&S and VV&A. This problem is exacerbated by the limited awareness of M&S management and VV&A practitioners about potential current and evolving technology to facilitate more effective and affordable VV&A. However, it appears that the time may be appropriate for major advances in application of M&S VV&A technology. Increased emphasis is being placed upon M&S use in system design, testing, and acquisition, as illustrated by the Simulation Based Acquisition (SBA) and Joint Experiment (JE) programs, and upon model-based decision aids for operational planning and execution. The Department of Energy (DOE) Accelerated Strategic Computing Initiative (ASCI) program includes a major software development component (with some emphasis on V&V of codes used in computational science and other areas of “grand challenge” problems) as well as the ASCI emphasis on advances in computational capabilities. Continuing computational advances and improvements in software development environments make automation of M&S V&V more viable just as they have already demonstrated such automation viability in software V&V. However, it should be noted that procurement officials, project managers and planners also have to be aware of the benefits of leveraging tools used in M&S development for V&V efforts so that contracts, etc. will be written to effectively accommodate exchange and sharing

of information, data and tools necessary for these benefits to be realized.

VV&A tools and technologies should be able to reduce program cost and risk if used properly. However, the importance of making the necessary investment to enable use of such M&S VV&A tools and technologies has not been widely recognized within DoD or elsewhere. In part, this situation exists because there is very little reliable cost benefit information available relative to M&S VV&A. Available cost information is not well organized for effective analysis (no standard cost element identification exists, useful and widely accepted metrics do not exist, etc.). This reduces the basis for cost benefit assessments to either mere postulation or to argument by analogy through comparisons between the dearth of tool use to support M&S VV&A with the more extensive application of automated tools in the software V&V arena.

It appears that commercial forces will continue to drive the development of software V&V technology more rapidly than M&S management and VV&A personnel are likely to assimilate and exploit fully. However, that may not be the case for technology that is peculiar to M&S VV&A that is otherwise not generally applicable for software V&V. The stimulus of government research and development (R&D) funding may be required for needed progress in this area.

A theme that was prominent in many parts of the workshop is the importance of talented people. Tools and technology can supplement, but will not replace the important role that knowledgeable people have in effective VV&A. Advancement in M&S and V&V theory can lessen dependence upon the most talented people as standardized formalisms (which theoretical advances enable) can be employed successfully by a larger group of people to VV&A problems.

2. Recommendations

There needs to be a sustained educational campaign to ensure that M&S managers appreciate the importance of VV&A, understand the cost-benefit potential of VV&A for their applications and understand the resources required to exploit VV&A technology in ways

that are both effective and affordable. This educational campaign must also ensure that VV&A practitioners are aware of available methodologies, techniques, tools, technologies and the implications of their application or non-application. No single organization is likely to stimulate or provide the total impetus needed for such an educational campaign; instead *each of the MORS Sponsors, SCS leadership, DMSO and others are encouraged to establish educational campaigns within their spheres of influence or provide the necessary resources to allow their people to benefit from the educational campaigns of other organizations.* Such educational campaigns must be multi-faceted, not only addressing audiences of VV&A practitioners through short-courses, conference presentations and articles in peer-reviewed trade journals, but also addressing M&S managers.

Several areas of research are required. At the most fundamental level, a relatively comprehensive survey of available VV&A tools and technologies is required. This survey should address how such tools and technologies should be used properly, identify appropriate applications and link tool use to phases of the M&S lifecycle. Information in this report can contribute to that survey, provide clues about how the information might be structured and pointers to some of its locations. Information resource requirements for tool use is also needed, such as data, personnel, training, equipment and financial considerations. Research should include establishment of a repository of VV&A tool information that identifies prior tool uses, results of tool application and costs of use. This repository may be either new or included within an existing repository. In addition, some level of support for basic research related to VV&A is indicated. This arena has been neglected to date, and such investment is needed if the long-term promise of VV&A improvements from technology advancements is to be fully realized. The development of a formalized methodology is also needed to assist users in determining how good a simulation must be if it is to support a particular kind of application. When such guidance can be reduced to formalized methodology, it becomes amenable to automation, with the consequence of enhanced VV&A effectiveness concurrent with reduction in the

cost of performing VV&A. In addition to DoD investments in research, agencies external to DoD that support basic M&S research, such as the National Science Foundation (NSF), other government agencies, commercial enterprises or private foundations, should consider the urgent need for more rapid advancement of VV&A methodologies and technologies when dispersing their funds. A corollary to the above is the necessity for sharing information developed by such research throughout the M&S VV&A community

Development of a widely accepted and widely used way to identify and describe different VV&A perspectives is also needed to reduce communication confusion among disparate

elements of the M&S and VV&A communities. Concomitant with development of such standard perspectives (views) would be elaboration of VV&A-related terminology to provide greater precision of meaning. Specification of VV&A cost elements must be included in this work, so that meaningful VV&A cost data can be captured to provide a factual basis for development or refinement of VV&A cost models.

In addition to the above general recommendations, the M&S VV&A community should also give attention to the more specific recommendations contained within the synopses from the three working groups and the Synthesis Group.

SIMVAL 99 Structure and Process

SIMVAL 99 employed plenary sessions to start the workshop, to facilitate cross-fertilization of ideas among its several groups each day, and to provide for communication of insights at the end of the workshop to all participants. In the opening plenary session, CAPT Dennis McBride (Office of Naval Research, Program Manager for Medical S&T) brought the keynote address, which challenged SIMVAL 99 participants to discover ways to keep VV&A from being outpaced by the speed of general computation and software advance. Col Kenneth Konwin, Director of the Defense Modeling and Simulation Office (DMSO), continued the opening plenary session with a V&V technology to calibrate SIMVAL 99 participants about current technology capabilities. A cautionary perspective on VV&A from Dr. Paul Davis (RAND) closed the opening plenary sessions. He noted issues of research base, bureaucratic mischief that impedes high-quality analysis, and opposing trends in commercial off-the-shelf software, some of which help and some of which hurt the cause of VV&A, and suggested principles for VV&A related tools, illustrating some of the points with examples from recent work. Several displays and exhibits about V&V technology and tools were available for SIMVAL 99 participants on the first day of the workshop.

The workshop attendees were divided into three working groups (identified below). The working groups occasionally subdivided to accomplish their responsibilities more expeditiously. A Synthesis Group facilitated communication of significant points among the working groups and assisted the SIMVAL 99 co-chairs in managing the workshop. More information about SIMVAL 99's organization, leadership, agenda and processes may be found in the SIMVAL 99 Terms of Reference (TOR) in Appendix A.

1. Working Group 1: Verification

Technology: Topics which WG 1 addressed included automated requirements/specification-testing and CASE tools, as they are used in the context of modern simulation paradigms (object oriented based simulation, distributed simulation, extensive use of Artificial Intelligence (AI) and other adaptive methodologies, etc.). Descriptive formats and their interactions (e.g., this is where

data/meta-data issues would reside) is a subset of verification technology. The emphasis of this WG was on identification of available tools and their applicability, especially to military uses of M&S.

2. Working Group 2: Validation Technology and Methodology: WG 2 focused on applications of technology to support:

- a. Subject Matter Expert (SME) selection, orientation, management, use, etc., especially in conceptual validation processes (and also in results validation)
- b. Correlation of representational fidelity with application needs
- c. Criteria for establishing needed levels of simulation fidelity
- d. Automation/technology potential (e.g., animation) to support validation methodology
- e. Correlation among the various levels of simulation CMs (CMMS, simulation concept, simulation elements/sub-elements)

3. Working Group 3: Impact of Technology on VV&A Costs: WG3 addressed identification of VV&A cost elements, costing algorithms, and rules-of-thumb.

4. Synthesis Group: The SG provided a mechanism to ensure cross-fertilization of ideas among the working groups, and to integrate and synthesize ideas from the workshop. Members of the SG participated in working groups as a means of facilitating conceptual synthesis and integration.

Of the 115 people who participated in SIMVAL 99 (listed in Appendix C): 33 were assigned to WG 1 (Verification Technology), 35 to WG 2 (Validation Methodology and Technology), 16 to WG 3 (Impact of Technology on VV&A Costs), and 7 to the SG. Just a few people changed working groups during the workshop. Members of the Synthesis Group participated in the working groups as needed to facilitate cross-fertilization of ideas among the groups and to help the SIMVAL 99 Co-Chairs keep the working groups focused on their assigned responsibilities.

Thirteen attendees participated only in the opening plenary session of the first day. The remainder consisted of the workshop leadership (SIMVAL 99 Co-Chairs) and support team from the MORS office and JHU/APL.

SIMVAL 99 had a reasonable balance in the organizational representation of its participants, as indicated:

Participants

Military	14
Army	5
Navy	5
Air Force	4
Government Civilian	25
FFRDC/UARC	22
Industry	41
Academe	5
Non-US	3 (from Australia, Germany, and The Netherlands)

SIMVAL 99 Working Group and Synthesis Group Synopses

The following pages provide synopses from each of the three SIMVAL 99 working groups and from its SG. These materials provide more detailed insights about findings and observations than presented earlier in the report. These synopses also contain recommendations, some of which are not the same as recommendations presented earlier in this report since these recommendations are from the particular perspective of the group. The earlier recommendations balanced perspectives of the groups and of the larger M&S community with its VV&A components.

Leadership and participants of the groups are identified at the beginning of each synopsis so that the reader can appreciate the breadth and depth of experience and associations which contributed to the materials in the synopses. Additional information may also be found in Appendix D about the briefings presented to the working groups and in the SIMVAL 99 Annex which contains both the briefings presented to the groups and their outbriefs to the workshop (note: most of these briefings are not annotated).

SIMVAL 99 Working Group 1 (Verification Technology) Synopsis

Working Group 1 Leaders:

Co-Chairs: Dr. Osman Balci (Virginia Tech)
Mr. Robert Lewis (Tec-Masters, Inc.)
Reporter: Ms. Susan Solick (US Army TRAC)

Participants (33 including WG 1 leaders):

Arthur, DR James	Virginia Tech
Brasse, MR M.H.H.	TNO Physics and Electronics Lab (The Netherlands)
Buckley, MR Joseph	Lockheed Martin-Government Electronics Systems
Cantwell, MR Larry	US Army TRACDOC Analysis Center
Chambers, MR Joseph Steve	Space and Missile Defense Battle Lab
Christensen, MR Peter	The MITRE Corporation
Crooks, MR Mark	RAND
Dickerson, MS Theresa	CAS Inc.
Eirich, MR Peter	Johns Hopkins University/APL
Gibson, DR Forrest	Joint National Test Facility
Haddix, MR F. Furman	University of Texas at Austin
Hagerdon, MS Linda	Space & Missile Command
Iwatake, MR Brian	Naval Undersea Warfare Center (NUWC)
Jordan, MR Jack	BMH Associates
Kollmorgen, MR Gary	BMH Associates, Inc
Leake, DR Charles	JWARS Office
Mair, MR Hans	IDA
Martin, MR Michael	Naval Air Warfare Center
Martin, MS Terri L Schrimsher	US Army Space and Missile Defense Battle Lab
Michelsen, Randy	Los Alamos National Laboratory
Mihaloew, MR Reed	The MITRE Corporation
Nance, DR Richard	Virginia Tech
Prosser, MR Terry	Logicon
Ravenel, MRS Cynthia	USA Aviation and Missile Command
Sargent, DR Robert	Syracuse University
Senko, MR Robert	Delfin Systems (DMSO)
Smith, Capt Sandra	JADS Joint Test Force
Spriesterbach, MR Thomas	Johns Hopkins University/APL
Strickland, MR Edward	Analex Corporation
Wallace, MS Dolores	US Department of Commerce

This synopsis has three parts. The first part identifies the invited presentations to WG 1 during SIMVAL 99. Content of these presentations is included in the SIMVAL 99 Annex. Because WG 1 functioned as two sub-

groups for part of the workshop, each of which produced a synopsis of ideas about verification technology, it was decided to provide these two synopses as the second and third parts of this synopsis for WG 1 since there was not adequate

time during the workshop to produce a single, fully integrated synopsis that properly represented the perspectives of both subgroups. This approach provides the reader with a fuller appreciation for topics addressed during the workshop, and provides two complementary perspectives about current and future verification technology.

1. WG 1 Invited Presentations

The invited presentations are listed in the order in which they were actually presented. It had been planned originally for them to be presented in the order indicated by the numbers in parentheses (just in front of the presentation title) so that a "from beginning to end" perspective about verification processes could be obtained. The arrangement of these presentation materials in the SIMVAL 99 Annex follows the order originally planned.

- (1) "M&S Verification Technology: An Overview" by Osman Balci: to identify the issues and problems to be addressed during the workshop.
- (7) "Overview of Six Major VV&A Processes and Associated Cost Models" by Robert O. Lewis to a combined session for Working Groups 1 (Verification Technology) and 3 (VV&A Costs)
- (6) "M&S Implementation Verification" by Richard E. Nance
- (5) "M&S Design Verification" by Delores R. Wallace
- (2) "M&S Requirements Verification" by Gary Kollmorgen
- (3) "M&S Requirements Verification" by Randy Michelsen
- (4) "M&S Conceptual Model Verification" by Furman Haddix

2. Synopsis from Subgroup A of WG 1

a. Topics Addressed:

- Findings/observations on the State of Verification Technology
- Findings/observations on the Near Term Potential for Verification Technology
- Findings/observations on the Far Term Potential for Verification Technology
- Issues

b. Findings and Observations on the Current State of Verification Technology

- Automation is critically needed to effectively and affordably conduct M&S verification.
- Component-based software development is an effective and affordable way of creating M&S applications and conducting M&S verification. A verified model component can substantially decrease the M&S verification effort when reused appropriately – thereby significantly decreasing the time and cost of M&S development.
- Success in the application of the current state of the verification technology is very much affected by employment of skilled personnel. Education and training in the area of technology for M&S development, especially in regard to VV&A, appears to be less than what is needed to fully exploit current capabilities.
- Terminology continues to pose serious communication problems for M&S and VV&A practitioners and others due to the diversity of the M&S community. Definitions of terms, even when agreed upon, may be interpreted differently, incorrectly, liberally or loosely. Such inconsistent use of M&S verification terminology adversely affects the development, use and dissemination of the verification technology.
- M&S verification technology heavily relies on software verification technology. Advancements in M&S verification capabilities mainly come from the software engineering discipline. This requires M&S verification professionals to be knowledgeable about software verification technology and associated CASE tools so that the software aspects of M&S verification can be addressed effectively.
- Lack of journal-quality peer-reviewed publications is a serious problem, which hinders advancement and dissemination of information about M&S verification technology. Incentives or encouragement for peer-reviewed publication within either the government or industry M&S

communities seem to be lacking. This problem manifests itself in the following example. Neither the VV&A Area Editor of the *ACM Transactions on Modeling and Computer Simulation* nor the Validation Associate Editor for *Simulation* have received submission of papers specifically addressing VV&A during the last two years.

- Significant advancement (in the near term) of verification technology specifically oriented toward M&S development and application is likely to be achieved only if substantial funding is provided for this purpose (as a stimulus) by government agencies such as DARPA, Office of Naval Research (ONR) and DMSO.
- Current verification technology is very rich in terms of non-automated techniques, many of which can be employed for M&S verification throughout the entire M&S development life cycle. Such techniques are described in contemporary VV&A literature, such as those identified in the SIMVAL 99 Terms of Reference (TOR), read-ahead package and handout materials.

c. Findings and Observations on the Near Term Potential for Verification Technology

- Many Computer-Aided Software Engineering (CASE) tools are available commercially that could be used to provide much of the automation needed in M&S verification. This automation is needed for more effective and more affordable M&S verification. Exploitation of these capabilities requires that M&S verification personnel become familiar with available CASE tools and use them as much as possible — it also requires that M&S management make necessary investment in procurement of such tools and personnel training for their use.

d. Findings and Observations on the Far Term Potential for Verification Technology

- Component-based M&S development technology, when created, may be the “silver bullet” which enables both effective and affordable M&S verification.

- Development of software tools to provide automation *specifically* for M&S verification should result in more effective and more affordable M&S verification.
- Availability of more appropriately educated and trained VV&A personnel should result in more successful applications of M&S verification technology.

3. Issues

a. Is there a lack of identifiable, qualified V&V personnel?

- **Discussion:**
- **Q:** How does this differ from the lack of software engineers (e.g., engineers, managers and practitioners)? It's the same problem.
- **Q:** Is there really a shortage? Or can we just not identify the right people? Is it the skills or the bodies we are talking about? There is very little agreement on what criteria is necessary regarding training, education or skills necessary for M&S (or M&S V&V).
- **Q:** Are we talking M&S or V&V? We need to identify appropriate M&S people first. The lack of skill in simulation is why we have a lack in skill in the V&V arena. The issue is the identifiability of qualified people. Organizations are assigning unskilled or inappropriately skilled people to accomplish this important task. There is no job in the M&S or V&V category in many organizations. This leads to a lack of training in these areas.

b. Should there be a quality assurance (QA) process? If so, then should it include V&V?

- **Discussion:**
- QA applied to M&S examines quality features of the model itself. The focus in M&S V&V has been on validation rather than verification. This is why “QA” is M&S mission oriented.
- **Q:** Should V&V be de-emphasized and QA be given more emphasis (i.e. keep V&V back in the software development process where it started)? Both are needed. QA focuses upon process and is normally performed exclusively by the

M&S developer; V&V focuses upon the product and may be performed in part by those who are not part of the M&S development team, increasing the potential for increased objectivity.

c. Should methods drive tools rather than tools driving methods?

- **Discussion:**
- It happens the other way around too often.
- **Q:** Shouldn't the objectives drive the methodology?
- Picking tools for each phase is not optimal. We should try to capture the idea of developing a V&V methodology and identifying an environment to support that methodology.
- **Recommendation:**
- VV&A literature, such as the DMSO RPG for VV&A, needs to identify appropriate V&V methodologies for each phase of the M&S lifecycle and M&S development and application process.

d. Should a uniform V&V procedure be applied to all M&S projects? (i.e., One size fits all?)

- **Discussion:**
- There are many variables that influence the amount and kind of V&V that should be applied to an M&S project. These include the type and size of the M&S, its intended use, tools used in developing the M&S, fidelity expected of the M&S, maturity of the M&S project and its developer, etc. Thus, it should be obvious that one size of V&V does not fit all M&S projects.
- **Recommendation:**
- The level of the V&V effort should be determined by appropriate consideration of factors such as those mentioned about and also be commensurate with the level of the overall M&S development effort, which may include:
 - Developer V&V
 - Combined developer/customer V&V
 - Independent V&V (Note: "Independent" should not be construed as "isolated.")

e. Should there be more training and education provided for VV&A? (short courses, university programs, etc.)

- **Recommendation:**
- Such training and education should be M&S-oriented and not solely oriented toward VV&A in isolation – M&S training and education should always include VV&A as part of its curriculum.

f. Should there be more funding resources for basic research in M&S and VV&A?

- **Discussion:**
- Resources identified in the SIMVAL 99 TOR note that M&S progress is impeded by the lack of generally accepted, comprehensive theory for M&S development (and its elements, such as VV&A).

g. Should M&S development methodology be better integrated with the VV&A processes?

- **Recommendation:**
- As a whole, the M&S community needs to do a better job of following the guidance in this area provided by the DMSO RPG for VV&A and other contemporary VV&A publications.

h. Should increased awareness of VV&A throughout the M&S community be made a priority?

- **Discussion:**
- The M&S community at large has limited understanding of VV&A and related issues.
- **Recommendation:**
- The MORS Sponsors, SCS International leadership, and SIMVAL 99 should consider how the M&S community at large can be better informed about VV&A issues – and then take appropriate action.

i. Do distributed simulation and parallel discrete event simulation (DES) pose even greater challenges for M&S VV&A?

- **Discussion:**
- Yes. Many of these challenges occur because of M&S complexity and size, which makes comprehensive testing both difficult as well as time-consuming and resource intensive.

j. Do we need any special attention to V&V of reused objects following component-based engineering or object oriented paradigm (OOP)?

- Discussion:**

Yes. Just because a component passes a V&V test suite/review at the component level does not ensure that component will always work and perform correctly when combined with other components. V&V must always be addressed as a multi-layered process with iteration as needed to ensure credibility and suitability of both individual components and their combined use.

4. Synopsis from Subgroup B of WG 1

a. Phase-Specific Verification Processes

Verification typically consists of a set of phase-specific processes including:

- Requirements Verification
- CM Verification
- Design Verification
- Implementation Verification

Verification depends heavily upon and is significantly affected by the type of model and simulation (M&S) to which it is applied. Because of the differences in application and the vast differences in size, complexity and fidelity of various M&S, it must be realized that none of these verification processes is a "one size fits all" approach. With this in mind, there are certain activities that are always performed on virtually every V&V program. These can be considered *foundation elements*. Then, because of the differences in M&S and its application, there are electives. So, much like a curriculum, there are required activities and elective ones. Moreover,

even in the required or foundation elements there will be variations in the specific tools and techniques used for problem solving. These decisions are based on corporate culture, sponsor preferences, developer engineering environments, GOTS/COTS tools and the size and significance of the M&S product to which V&V is being applied.

This report reminds the V&V practitioner to select the tools and techniques based on some form of economic and technical analysis. Figure WG 1-1 contains a list of considerations that should assist in this process of tool and technique selection. Further, this report does not endorse specific tools but rather uses specific ones *only* as examples of the types of tools under discussion. In general, the simpler tools often tend to be adequate for V&V, whereas they may not always satisfy the M&S developer's needs. Thus, major objectives of tool selection should be to acquire tools that are easy to learn, offer the specific capabilities needed and are as economical as possible while providing the necessary capabilities. Tool selectors should try hard not to trade essential features for cost savings, as this would be highly counterproductive.

One of the recommendations described in Figure WG 1-1 focuses on selection. To further expound upon this idea, the V&V planner must understand the tasks that need to be accomplished in each phase. From this list of essential activities, V&V must determine which ones need a formal method or procedure. Those needing formal methods are examined to determine whether a tool or technique is preferred. When a tool is indicated, perform the steps in Figure WG 1-1.

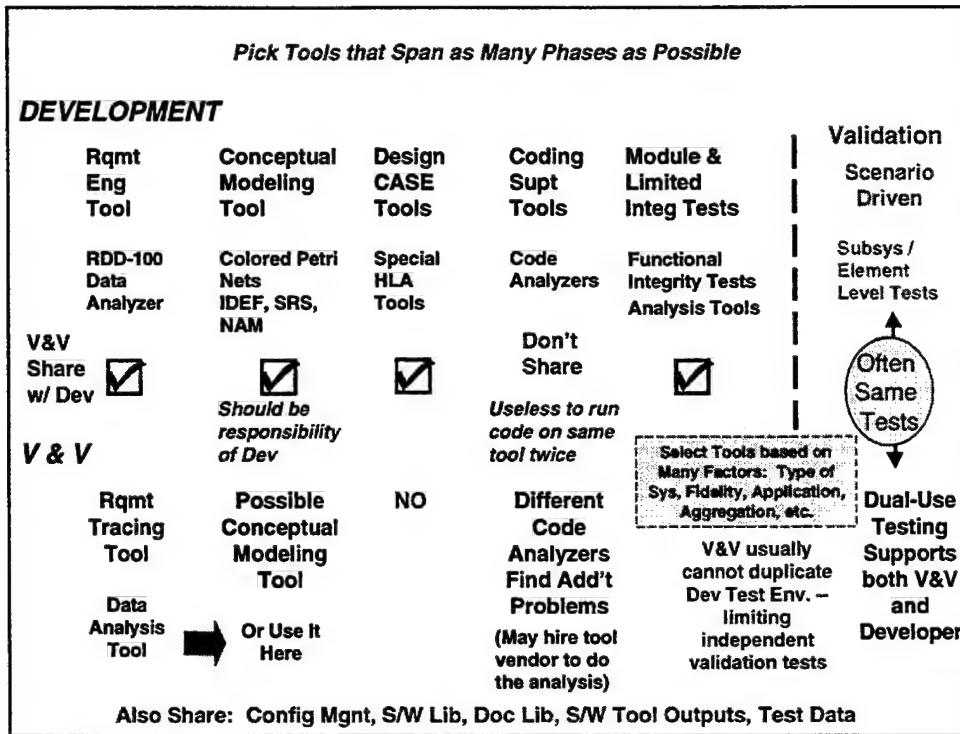


Figure WG 1-1. Tool Selection Considerations

b. A Generic Tool Profile

Figure WG 2-2 provides a high-level view of the M&S development cycle and associated VV&A phases. The main purpose in this form of representation is to indicate:

- How closely aligned V&V is with development or preparation of the M&S.
- How V&V can share and leverage off development tools, products and processes.
- That V&V needs some tools and techniques of its own regardless of how rich the development tool set is.

There is also some possible variation in where (which phase) a particular tool or technique is used because of variations in the development cycle. For example, in legacy M&S, V&V is likely to have little or no opportunity to leverage off development artifacts and tools and, therefore, may be required to “go it alone.” In such cases, V&V will require a sufficient set of tools to support all of the essential tasks, with selection based on the goodness and maturity of the existing product, its intended use, criticality of the application and various other factors.

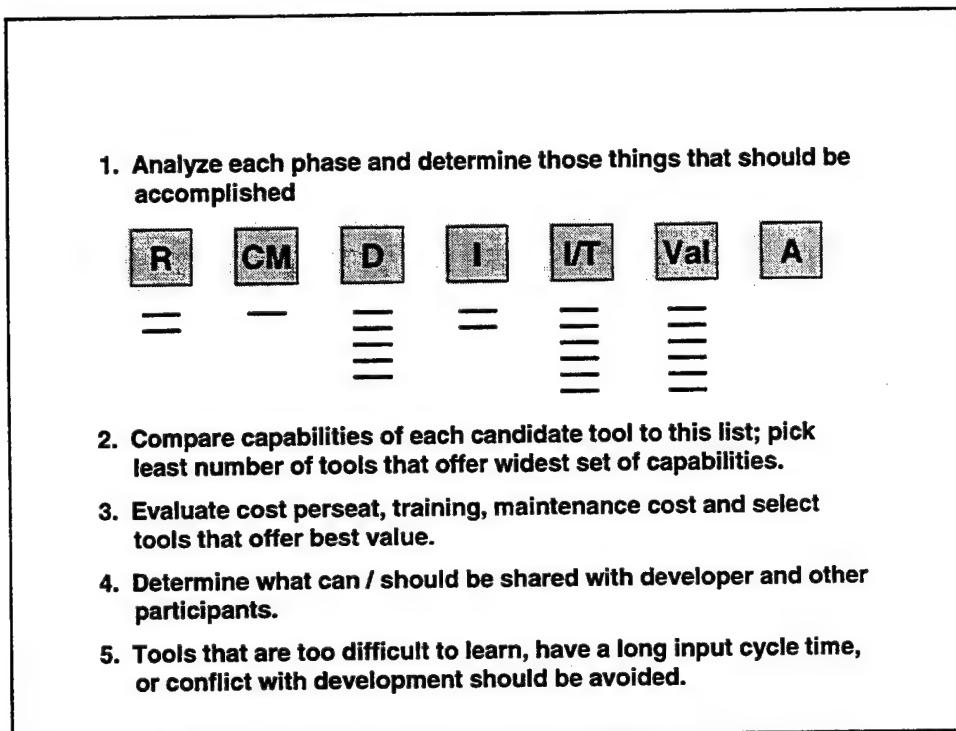


Figure WG 1-2 Typical Tool Profile

Notice also that the M&S developer or provider should be required in its contract to share such things as the configuration management system and records, software and documentation libraries, test data and any archived data and information from the tools used to build, analyze and evaluate the M&S product. It may also be possible in some cases to use an existing Software Engineering Environment (SEE) or test bed that was used to build and/or test the M&S. Although

this is far from a complete treatise on the subject of verification, Figure WG 1-2 helps establish a contextual framework for the specific sections that follow.

Some kind of organized approach to VV&A costs is required if meaningful cost estimation for VV&A activities is to be viable. Figure WG 1-3 illustrates the kind of factors that need to be considered in estimating VV&A costs.

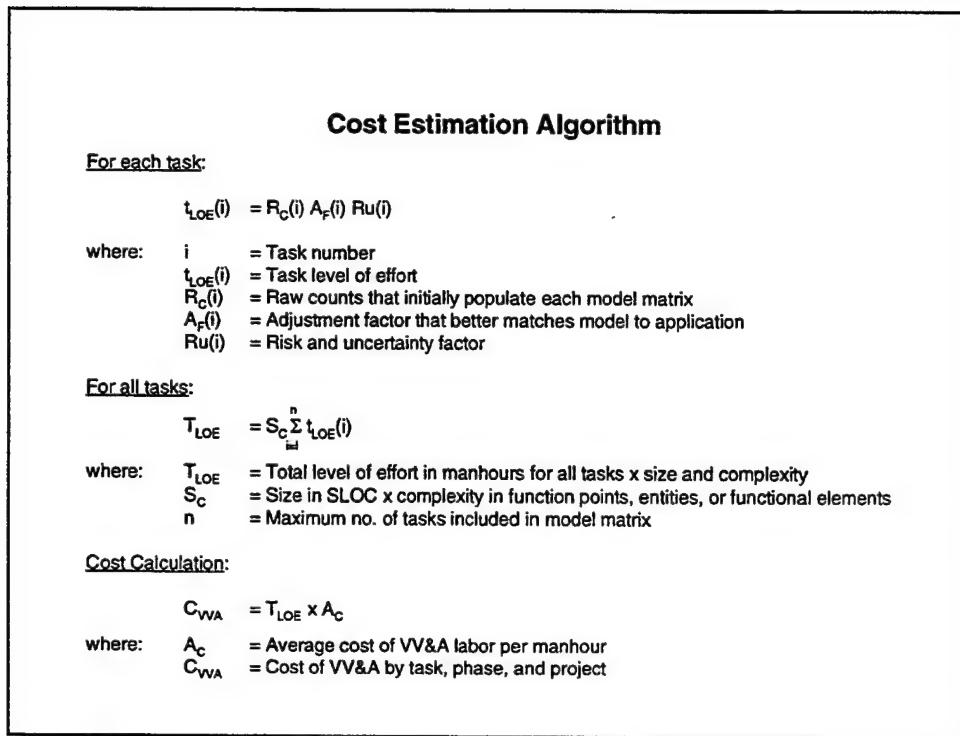


Figure WG 1-3 Cost Estimation

c. Issues and Recommendations

Requirements: Verification would benefit greatly from formal methods and better, more comprehensive CASE tools; however, their cost benefits are most apparent when embraced first by the developer and then shared by V&V.

CM Verification (and Validation) badly needs a unified, standard approach to defining CMs. This, in turn, spawns the need for a tool or tools to provide this service. It may require one approach for High Level Architecture (HLA) based M&S that use the CMMS and a another for those M&S that do not.

New development methodologies for M&S design and coding that include fourth generation languages (4GLs), autocode generators, etc. will require new adaptations of the VV&A process. These approaches will typically eliminate most of the Implementation Verification activities.

Current CASE tools do a good job on design and code and, as long as these tools are shared with V&V, this is not a particularly problematic issue. V&V should be discouraged from instituting

elaborate CASE tools as part of the V&V approach that are different from those used in development.

Procurement organizations need to be aware of the needs of V&V to share tools and data from the developer and include these requirements in the RFPs and SOWs for the development contracts to ensure adequate support for V&V. The opinion of the group was that VV&A needs better propagation throughout the M&S community.

Recommend that our university system and continuing education curricula be encouraged to increase emphasis on V&V and M&S tool technology.

Increase flow from projects into M&S Repositories for case studies, tools, methods, and cost data.

5. Findings and Observations: Requirements

Verification: Current State

- a. There is a need to establish a better understanding of the problem by all

participants — customer, user, developer and VV&A practitioners — at the beginning of the M&S effort

- b.** There is a lack of analytical formalism and accompanying methodology in this phase
- c.** Tool selection should be based on cost versus tool compatibility and availability as well as its ability to match the application
- d.** There is a great need for training and education as well as specific talent and acquired skills
- e.** Tools need to be extensible and scalable to a wide range of VV&A efforts
- f.** Data needs to be persistent, maintainable and easy to change and verify
- g.** The impact of large, multi-user/multi-site projects needs to be considered in the VV&A methodology and tool selection process.

6. Requirements Verification: Future Needs

- a.** Better, cheaper requirements analysis tools
- b.** Improvements in requirements management
- c.** Improved capabilities to support analytical studies especially with tools
- d.** More complete integration with downstream phases and tools
- e.** Enhanced formal processes and methods, tools and formal specification languages
- f.** Repository of requirements characteristics — persistent, traceable, and reusable.

7. CM Verification: Current State

- a.** Tool selection should be based on cost versus tool compatibility and availability as well as its ability to match the application and span between requirements and design phases
- b.** Most CMs are not clearly understandable by all evaluators
- c.** Should the “use case” analysis from Unified Modeling Language (UML) be applicable to CMs?
- d.** Bi-directional tracing between CM and object model is required
- e.** Lack of a widely accepted view of the CM reduces its utility
- f.** Lack a Conceptual Modeling tool that can and should be used throughout the rest of

the M&S development and VV&A processes.

8. CM Verification: Future Needs

- a.** Need to continued development and V&V of the CMs of the Mission Space (CMMS) and other authoritative sources
- b.** Need standard methodologies and tools to build CMs
- c.** Enhancement of CMMS and other data sources and extraction tool sets that help automate and assist the building of the CM
- d.** Consistent practices for inputs to CMs
- e.** Automated traceability from requirements to the CM and from the CM to design.

9. Design Verification: Current State

- a.** Although they sometimes do, V&V tools should not compete unnecessarily with developer’s tools (acquire necessary copies for V&V)
- b.** Lack of comprehensive tools to examine and evaluate:
- c.** Key algorithms, behaviors, performances (e.g., states, functions)
- d.** Data and databases
- e.** Interfaces (both internal and external)

10. Design Verification: Future Needs

- a.** Repository of data and information describing design errors by type and class
- b.** Automated testing aids associated with design that would become part of this repository
- c.** More effective tools to analyze algorithms, data and interfaces as well as control and data flow or that represent the object oriented views of the design in easy to understand notation
- d.** Visualization tools to examine consistency across different design methodologies within a single end product.

11. Implementation Verification: Current State

- a. Difficulty in defining how to select and ensure adherence to coding standards and good practices
- b. Highly dependent on subject matter knowledge (programmer)
- c. Need to improve process of selection of appropriate metrics for specific types of problems
- d. Need to improve the use and effectiveness of support tools, which is heavily dependent on developer's software engineering environment (SEE).

12. Implementation Verification: Future Needs

- a. Use of new, more productive and easier to analyze languages for modeling and simulation
- b. Static and dynamic code analyzers for M&S languages that currently have none
- c. Better maintenance and easier reuse of legacy models and analytical tools
- d. Appropriate application of talent and emerging technologies

SIMVAL 99 Working Group 2 (Validation Methodology & Technology) Synopsis

Working Group 2 Leaders:

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Mr. Tom Ruth (AMSAA)
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Faix, MR Joseph	SAIC/JADS
Fujio, MR Hirome	Computer Sciences Corporation
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The synopsis begins by identifying the briefings presented to Working Group 2. Then there is a brief overview of how WG 2 functioned. Then findings /observations about current and future

validation methodology and technology are presented.

1. WG 2 Briefings:

- a. "Modular Semi-Automated Forces (ModSAF) Experimentation (VV&A, Physical Models, Data)" by John Thomas
- b. "A Construct for the Use of SMEs" by Scott Harmon

2. WG 2 Overview:

- a. The TOR provided guidance for WG 2 deliberations. This guidance focused the discussions on the following areas.
- Subject Matter Expert (SME) selection, orientation, management and use,

especially in validation of CMs, and simulation outputs.

- Fidelity
- Correlation of representational fidelity with application needs
- Criteria for establishing needed levels of simulation fidelity
- Technology (e.g. automation) potential to support validation methodology
- Simulation CMs - correlation among the various levels.

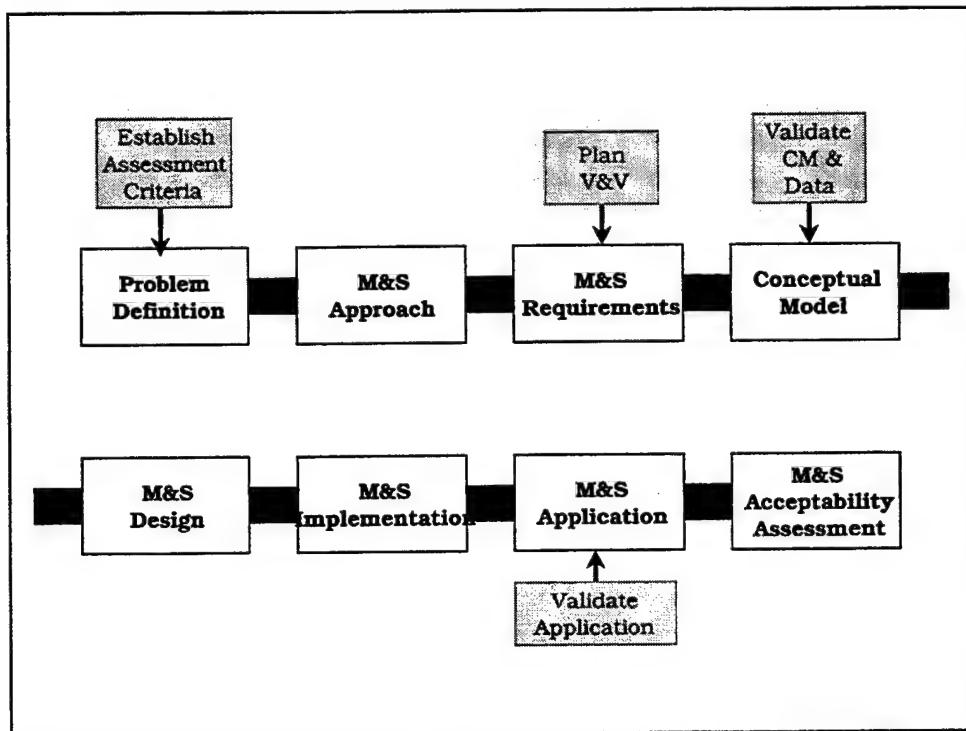


Figure WG 2-1 M&S Development Cycle and V&V

WG 2 organized its discussions according to the various phases and validation tasks that parallel the development cycle. Figure WG 2-1 depicts the M&S development cycle described in the RPG. The four validation tasks that include or affect validation tasks are described below.

- Developing validation criteria - provide standards for comparing models with the real world.
- Validating the CM - determine the degree to which the CM is an accurate representation of the real world from the perspective of the intended uses of the model.
- Validating the input data - determine that the data for use in M&S is suitable and appropriate for the model's intended use.
- Validating the application - assess that the developed M&S outputs compared within specified error with what is known about the real world using the validation criteria

The discussion concerning validation criteria led to the identification of several elements that were needed to adequately specify validation criteria. These are:

- Assumptions and limitations related to the problem or design of experiment

- Required Accuracy
- Required Scalability
- Level of confidence required in validation results
- A means of determining what types of validation are appropriate for this problem
- An issues-to-measures-to-data dendritic

The discussion then focused on what tools were or would be useful to help one identify and present a full description of the validation criteria.

The discussion concerning CM validation rapidly turned into a discussion of just what constituted a CM. The group agreed upon using the definition that is summarized in Chapter 1 of the current DoD VV&A RPG. This summary states that the following elements constitute a CM:

- Description of Requirements - the modeling pieces
- How the pieces are planned to interact
- How they will work together (integration approach)
- Descriptions of equations & algorithms to be used

- Assumptions & limitations growing out of selected equations & algorithms
- How these assumptions and limitations are expected to impact on the simulation's ability to meet the problem requirements

The group concurred that CMs should be described with this level of specificity.

Other issues related to CM validation that were discussed included the types of SMEs and what qualifications they should have; what questions are appropriate to ask in SME reviews, what evaluation criteria should be used and what knowledge acquisition tools are appropriate. The topic of SME selection was pursued in some depth and included an abstract presentation that related SME qualifications to the nature of the problem.

SMEs are an essential part of any simulation validation effort. However, several constraints exist in order to maximize the value of their contributions that a developer must take into account to optimize the use of SMEs. The developer has a model needing validation (M) and the specified purpose intended for the model (P). From these, the SMEs must build their own internal models of the model or simulation and its purpose. This requires the SMEs to be able to perceive the model and purpose (ideally with minimum distortion). This process is seldom perfect — especially for complex models, for models with unfamiliar representations (e.g., neural networks) and for models with involved purposes or those unfamiliar to the SME. The developer must therefore take extra precautions to reduce the probabilities of distortion occurring during these transfers. After the SMEs have developed their internal models of the model under validation and its purpose, they must put those internal models into a form that they can compare with their knowledge of the domains of their expertise. This is essentially a normalization step. The SMEs then compare these normalized models with their expert knowledge to assess their validity for the intended purpose. Each of the arrows in this illustration represents an opportunity for distortion that introduces error into the validation process. Of course, any such error contributes to validation errors. The developer or validation agent or both must

recognize these error sources and choose SMEs and representations to minimize their effects.

This suggests several criteria for selecting SMEs to validate a particular model for a specific purpose. Obviously, the SMEs must possess the domain knowledge that relates to both the model under validation and to the purpose for which it is being validated. However, beyond this well understood requirement, several more criteria exist to reduce the possibilities of introducing errors into the validation process. In other words, simply choosing SMEs with the necessary domain knowledge is not sufficient to guarantee satisfactory validation. SMEs must be able to correctly perceive both model and purpose to form accurate internal models that they will then compare with their domain knowledge.

Inaccurate perceptions of model and purpose will lead to inaccurate validation results as surely as inappropriate domain knowledge. Developers must ensure that the SMEs understand the representations of these elements. These problems are often seen when models use representations that are unfamiliar to SMEs (e.g., production rules). SMEs must also be able to normalize their perceptions of the model under validation and its purpose and compare those perceptions with their domain knowledge. These steps are most often ignored by developers and validation agents who operate under the assumption that if the SMEs have the required domain knowledge then they can perform the required validation. Normalization and comparison errors are difficult to detect and probably result in far more validation errors than currently appreciated. Finally, the SMEs must be able to clearly communicate their assessments. This source of error can be minor in most cases with the proper SME selection. Many applications require multiple SMEs since no single person's domain expertise covers all of a model or its purpose. In these cases, the arrows in the previous slide represent communications between people, always sources of error and distortion.

In other more practical but less robust terms, a suggested list of the different types of expertise needed for a CM review include:

- Operational

- Analytic (possessing an understanding of the problem)
- M&S being considered
- Technology of the system(s) being modeled
- Modeling Techniques - Application Specific

The data validation discussion led to a list of questions about the data that are needed to adequately assess its quality. The questions that were identified are listed here.

- What is the source? (Data and Algorithms)
- Is it authoritative?
- What algorithms are implied or embodied in the data?
- Is it valid for intended use?
- How good does it need to be?
- What is the type, compatibility, format and accuracy of the data?
- What is the classification, cost and availability of the data?
- Are the data proprietary?
- What is the data pedigree?

The discussion of application validation began with a definition or explanation of what is meant by application validation. The WG agreed that it is a comparison of the model outputs to the real world and what we know about it and making a determination about its acceptability. This can be done using a number of techniques. The two principle approaches are quantitative and qualitative. The quantitative approach can employ statistical methods and usually is done either through results validation or benchmarking. Qualitative approach is usually done through face validation. The process recognized by the WG follows three basic steps: generate M&S predictions, collect real world data and compare the two methods to determine the best approach.

These discussions culminated in discussions about what tools and techniques were typically used in the various steps, what deficiencies were perceived and what improvements or advancements are needed to make the validation process more effective.

In pursuing these discussions, the WG agreed that the cost of validation is greatly influenced by the validation techniques selected, the tools employed, and especially the initial validation

requirements. The WG recognized that the most important factors that affect validation costs are:

- The determination of what types of validation are appropriate for a given problem or model development effort
- The determination of what level of confidence is needed in the model results so that the depth and scope of validation can be properly planned.
- The cost of obtaining real world data (from tests or operations) for use in validation.

3. Findings and Observations

- a. **The State of Validation Methodology is Marginal and The State of the Technology is Poor.** The need to Verify and Validate (V&V) M&S has been a requirement since the first model and simulation was written and has received increased emphasis with the past ten years. However, despite this emphasis and while the required validation processes are generally well known, they are not rigorously followed nor are integrated together today. Further, while it is fairly easy to derive many properties required for desirable tools, it is difficult to find tools that incorporate these properties. Some of the properties required are more difficult to derive. These would include selecting the right real world variables to be mapped in the CM. In general, the current state of validation is *brute force labor*. Using the Validation tasks identified above as organizing elements, a more specific discussion of these assessed states is discussed below.

- **Develop Model Validation Criteria.** There are many existing tools to support the methods described above. They include word processors, spreadsheets, database management systems, system engineering tools, subject matter experts (SME), Model and Simulation Requirements Repository (MSRR), statistical and simulation tools and knowledge acquisition and engineering tools. However, improvements in the tools were seen to be required. Knowledge acquisition and engineering was noted as

- offering a substantial challenge for improvement.
- Validate CM. Although some tools exist to support CM Validation, they were assessed to be particularly weak. Current tools include Computer Assisted System Engineering Tools (CASE) tools such as Paradigm Plus, Cadre TeamWork and Design/IDEF; "Dynamic" CASE tools for meta-simulations such as Design/CPM, ModSIM, ITHINK, flowcharting and structured walk-throughs.
- Validate Data. Current tools include database management systems to support the traceability of data and authoritative data sources, data quality engineering to assess the range within which the data is valid and any logical errors in the use of the data, and data modeling tools to show the relationship between data. Tools in this area were assessed to be mature for software engineering purposes, but weak for M&S requirements definition and management purposes.
- Validate Application. Current tools to accomplish this are numerous statistical analysis tools, visualization in two or more dimensions (MUSE technology), the use of After Action Reviews (AAR) that are interactive and provide model results in a manner understandable to the users, and SEDRIS-like tools. It was the consensus of the WG that current tools need to be significantly improved.

4. Near Term Findings and Observations for Validation Methodology

- Improve The Description Of Validation Methodology In The *RPG*. The WG concluded that while validation methodology is described *RPG* for general reference purposes that the description was incomplete for task planning and execution.
- Establish methodology for independent peer review of CMs. The WG recalled from previous meetings on validation that a promising approach for validating the CM was in having it reviewed by persons independent of the current M&S development effort who had built CMs for

other M&S projects. One individual from the WG cited his own experience as evidence that this was a sound practice.

- Analyze Current Validation Methods Towards Integrating Them Into A More Coherent Methodology. The WG assessed that individual validation processes were poorly integrated between themselves and that this fact mattered to the overall validation of the M&S being developed.
- Incorporate Continuous Process Improvements Into M&S Development. The WG observed that M&S development is largely an iterative process that cycles repeatedly from requirements analysis through applications. This cyclic effect begs for continuous process improvement in the sense of total quality management.
- Develop Guidance For The User And SMEs In M&S Development. The WG developed a model for SME involvement in the validation model that can be used in developing rules for SME involvement. Also, the Conceptual Model of the Mission Space (CMMS) and CM activities were identified as important to user involvement. Finally, the WG developed a generic set of model validation criteria that were linked to the intended use of the M&S that were determined to be an important mechanism for measuring validation success.
- Expand Methodology To Include Simulation Based Acquisition (SBA) And Joint Experimentation (JE) Requirements. SBA and JE are DoD concepts that envision new roles for M&S use. The WG concluded that it was important for DoD to investigate the implications of these concepts to the validation of M&S for these purposes. Also related to this finding, is the observation that the validation process in the distributed simulation environment is still not fully understood although efforts have been made previously to do so.
- Develop Tools Or Tool Sets Having The Identified Required Properties For Validation. (E.G. Develop Universal Tool Set To For Conceptual Modeling. Suggest starting a development of a CM template).

While the *RPG* has a fairly good definition and description of the CM and there are many known useful tools that could be used to assist in its description, the WG decided that there is insufficient guidance to determine when a sufficiently complete CM has been achieved to specify a design. Further, it is unknown what an objective description of a tool or tool set is necessary to achieve the objective CM. This difficulty is complicated by the iterative nature of CM development. Even after design or implementation is underway, the development process may revisit and revise the CM. However, while the CM may always be incomplete, it is believed that an objective CM can be defined for each M&S.

- Leverage instrumentation technology to improve the quality and scope of real data. Experience from STOW, ModSAF and A2ATD revealed the value of instrumenting M&S to generate data for configuration management, statistical diagnostics and AAR. The WG believes that instrumentation of M&S can be a powerful tool for validation.
- Conduct education in the use of technology to be compatible with the technology. The WG decided that the introduction of new methods and technology into M&S validation would be placed at a disadvantage if there were not parallel efforts to educate users and developers in their implementation. For example, the incorporation of new capabilities to provide statistical analysis such as for defining levels of confidence or risk would not be useful unless the users to relate these to meaningful measures.

5. Far Term Findings and Observations for Validation Methodology. Invest in research for the following areas:

- Modeling Theory To Better Understand The Relationship Between That Of The Real World And The Formal Systems That Represent Them. Validation requires linking model representations with the real world. Specifically, the CM is an

abstraction of the real world. How one chooses the finite subset of the real world and maps it into the CM is difficult. For example, there are no good rules for selecting what variables should be inputs or parameters in a model having great impact on the quality of validation. While it was observed that tools seldom are a replacement for talent, it was also noted that good theory is a talent enhancer.

- Collection of Reliable, Reproducible Experimental Data. Relating to the need for research into modeling theory for M&S development (and validation) is the need to conduct field tests in order to test the theory and to provide an analytical basis to validation testing.

6. Far Term Findings and Observations for Validation Technology. Invest in research for the following areas:

- The Measurement Of Human Performance (Both Human-In-The-Loop (HITL) And Human Representations). Human behavior replicated within M&S and interacting with M&S is problematic but also an important part of the validation problem. This aspect of M&S will become increasingly important in SBA and JE.
- Knowledge Acquisition And Engineering Tools. Requirements include development, analysis and conceptualization demand knowledge acquisition and engineering in order to transition the semantics of the real world into the syntax of a CM and its objective M&S. Currently, this is a labor intensive effort that provides great opportunities for technology to improve.
- Complexity (Modeling Information Based Phenomena). The WG observed that the state of the art in validating some real world phenomena varied between the phenomena being modeled. For example, many physics based phenomena such as ballistics are modeled in analytic expressions using assumptions that provide a high degree of confidence in their use. However, examples involving visualization such as target acquisition,

interactions of battlefield entities and other information-based phenomena illustrate the M&S community's need to

better understand how they can be modeled

SIMVAL 99 Working Group 3 (Technology Impact on VV&A Cost) Synopsis

Working Group 3 Leaders:

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Thomen, MR David	ETAS/SAIC

1. WG 3 Briefings

The following briefings were presented in WG 3.

- a. *Costing Of Model And Simulation (M&S) Verification, Validation, And Accreditation (VV&A) Within DoD — A Managed (Marginal) Investment Strategy* by Robert Gravitz and Bill Waite
- b. *Overview of Six Major VV&A Processes and Associated Cost Models* by Robert O. Lewis to a combined session for WGs 1 (Verification Technology) and 3 (VV&A Costs)
- c. *Advanced Distributed Simulation (ADS) Work Breakdown Structure*

(WBS) AS of 13 Jan 1999 by LTC Cannon

2. Introduction

Within M&S economics, in particular VV&A, there are both cost and benefit components as illustrated in Figure WG 3-1. We concentrated on the cost components. We identified M&S technologies and assessed their impact on VV&A costs. Then we cross-walked the technologies and cost to factors that either reduced or compounded V&V costs.

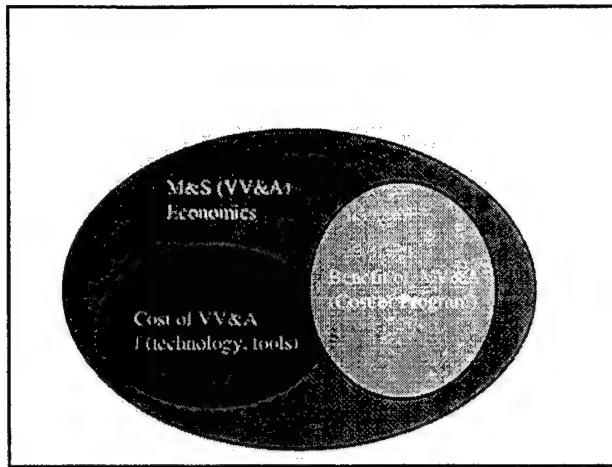


Figure WG 3-1 VV&A Interactions

3. Cost Factors Descriptions

We identified the following cost factors as influencing V&V costs:

- a. Stability of Requirements. Variability of Simulation Requirements as a consequence of the inherent instability of the problem or variability of user expressed needs/ Requirements
- b. Complexity of User Requirements. Number /complexity of Simulation Requirements as a consequence of the inherent difficulty of the problem
- c. Security Requirements. Classification and compartmentalization of information and security required to access that information (firewalls, etc.)
- d. Time Available. Schedule (calendar) driven program
- e. M&S System Documentation. Degree to which the system is well described in appropriate form (documents, etc.)
- f. Required Credibility. The degree of credibility of results or the stringency of level of proof required by authority
- g. Probability of risk x impact of risk. Net risk
- h. Size/complexity of Unit Under Test. Size/complexity of the Simulation system and /or components
- i. Maturity of The Simulation Development Process. Akin to SEI CMM but correlated to simulation development
- j. Availability of Reference Data. Availability of data used to compare

simulation results to (e.g. validation reference data)

- k. COTS/GOTS (make or buy decisions). Visibility (or lack thereof) into COTS (for example) and its inherent quality (or lack thereof) may impact the cost of VV&A; need to develop your own (GOTS) will impact cost of VV&A
- l. Competence Of V&V Execution Agents. Skill and ability to execute V&V tasks efficiently and effectively
- m. System Engineering Process. Quality and maturity of entire program management processes of the reference system (above Simulation development process)
- n. Consistency Of Enterprise Culture. Degree of shared appreciation of the mission space, simulation system, architecture, essential business and technical VV&A process

4. Technologies Area Descriptions

We assessed the potential for the following technologies to compound or reduce V&V costs.

- a. High Order Languages. Programming and simulation languages that provide a high level of functionality in a concise form.
- b. Integrated Development Environments. Software tools and methods that help organize and automate the development process.
- c. Telecom Infrastructure. Telecommunications facilities and

- c. **Telecom Infrastructure.** Telecommunications facilities and architectures available to support M&S development/use.
- d. **Computational Capability.** Speed, capacity and architecture of computing hardware.
- e. **Database Technologies.** Tools and methods of acquiring, storing and retrieving data/information.
- f. **Advanced Alternative Representations.** Advanced methods including for example, neural networks, fuzzy logic, knowledge and rule based systems, genetic programming.
- g. **Program Management Tools/Business Practices.** Methods and tools for planning, scheduling, control, budgeting and other tasks for program managers.
- h. **Automated Repositories.** Large scale distributed databases accessible to a wide user community, for example MSRR.
- i. **Knowledge Discovery in Databases.** Automated knowledge tools for research of database information and recovery of specific data and the mining of data based on AI techniques.
- j. **Analysis and Visualization Technologies.** Methods and tools for visualizing and analyzing attributes and relationships of the real world, the simulation system and related data.
- k. **Synthetic Environments.** Virtual environments that replicate and model, and permit immersion into, relevant operational context (includes some, but possibly not all of cognitive performance modulators — see SIMTECH 2007).
- l. **CM Forms/Notations.** Practices, representational schema and formal methods that facilitate precise specification of models.
- m. **Operational Practice.** Well-defined elements of technical and business practice of simulation and VV&A that facilitate efficient practice. Level of craft skills in VV&A.
- n. **Decision Support Tools.** Aids to managers and analysts for identifying and analyzing options.
- o. **Security/Encryption.** Methods and technology for protecting systems and data.
- p. **Standards.** Uniform practices and standards, including operational, system, and technical.
- q. **Test Generation Tools.** Methods and tools for automated generation of test cases.
- r. **Code Generation tools.** Methods and tools for automated generation of source code.
- s. **Scalability.** Tools and methods to change the resolution in a consistent manner; to change the breadth and/or depth of simulation with consistency.

Technologies	Cost Factors												
	Schedule time available	Size/complexity of UUT	Competence of executing agents	MS documentation	Nbr/complexity of user requirements	Consistency of enterprise culture	Avail of ref data	System eng process	Probability& Impact of risk	Maturity of sim dvp process	Security requirements	Stability of requirements	Required credibility
Program management tools/business practices	+	+	+	+	+	+	+	+	+	+	+	++	+
Knowledge Discovery in Databases	+	+	+	+	+	+	+	+	+	+	-	+	+
Standards definition	+	+	+	+	+	+	+	+	+	+	+	+	+
Automated repositories	+	+	+		+	+	+	+	+	+	-	+	+
Database technologies	+	+	+	+		+	+	+		+	+	+	+
Integrated development environments	+-	+	+	+			+	+	+	+	+	+	+
Operational practice	+	+	+	+		+	+	+	+	+			+-
Conceptual model forms/notation	+	+	+	+	+	+		+		+		+	
Computational capability	+	+	+	+	-		+		+		+		+
Test generation tools	++	+	+	+	+	+		+	+				
Analysis/visualization tools	+	+	+	+	+	+	++						
Code generation tools	+	+	+	+	+			+		++			
Advanced alternative representations	-	+	-	-	-			+	+	+		-	+
Synthetic environments	+	+	+	+	+	+	+				+	+	
Telecom infrastructure	++	-		+	-		+				-		
High order languages	+	+	+	+		-				+			
Decision support tools	+		+		+			+	+				
Scalability	+	-	-	+	+	+				+			
Security/encryption	-	-		-			+				+		+

Table WG 3-1 Cost Factor – Technology

Table WG 3-1 summarizes the impact of technologies based on their influence of V&V

costs. Additional considerations are summarized in Table WG 3-2.

Technology	Benefits to VV&A	VV&A Process / Activity Leveraged [Col. 2(2-3)]	Cost Avoidance	Acct Impact to Cost of VV&A	Apportionment of \$S DUE to Cost Functionality Impact Areas [B22-B31]
Analysis & Visualization Tools		a,b,e,g,h,j,k	time - helps correlate diverse or disparate pieces of info into a visual format	could be + or -	na 2,4,5,9,10,12,14
Synthetic Environments		b,c,d,e,g	sys dev costs, time, scheduling	could be + or -	na 1,2,3,4,5,8,10,12,14
Operational Practices		e,f,g,h	sys dev costs, time, scheduling	could be + or -	dependant on Practices involved +/- 4,5,6,7,8,9,10,12,13,14
Decision Support Tools		a,c,d,e		could be + or -	minimal 2,4,5,7,12,13
Security / Encryption Technologies	could aid distribution of info (across secure net), data pre-qualified	B,C,e,f,h,		potential + and -	na 3,4,5,8,10,11
Industry Standards ...	collaboration, consistency, traceability	b,c,e,f,g,h,i,k	time, scheduling	should help reduce	minimal 2,3,4,5,6,8,9,10,11,12,13,14
Test Generation Tools		c,e,f,g,h	sys dev costs, time, scheduling	should help reduce	na 2,4,5,7,8,12,13,14
Code Generation Tools		e,f,g,h	sys dev costs, time, scheduling	should help reduce	na 2,3,4,8,9,12,13
IDE & Implicit Processes		a,b,c,d,e,f,g,h		should help reduce	na 1,3,4,5,7,8,9,10,12,13
Advanced, Alternative Representations	Better representation, however - more difficult to train, understand & interpret	c,e,f,g		could add additional costs for training & implementation understanding	na 2,4,5,6,7,8,9,11,12,13
Telecom Infrastructures		a,g,h,i,k	time, scheduling	should help reduce	dependant on requirements & locations of parties involved +/- 2,3,4,5,8,10
Databases	shared use of data, consistency of form and format, documentation	a,b,c,d,e,h,i,j	time, data sharing, standardizing formats	should help reduce	dependant on requirements and amount of data & Practices involved +/- 1,4,5,6,9,10,11,12,13,14
Advanced Hardwares Capabilities / Computational Capabilities		a,b,e,g,k	time	should help reduce	na 2,3,4,5,6,7,8,10,12
High Order Languages	Documentation, SOA practices	e,f,g,h,i	time, code checking	should help reduce	na 4,5,7,8,12,14
Conceptual Model / Formal Specifications		a,b,c,d,e,f,i,k		should help reduce	direct relation 1,2,4,8,9,12,13,14
Knowledge Discovery, Search Engines, Data Mining, KDD	documentation of data VV&A	b,d,e,f,g	collection of data - finding best source or most appropriate data	could be + or -	minimal 2,3,4,5,6,7,8,9,10,11,12,13,14
Automated Repositories & Re-Use assets	makes data avail, ADS pre-qual data	b,c,d,e,f,h,k	increasing data, reduce research	should help reduce	depends on amount of data V&V required 1,2,3,4,6,7,8,9,10,12,13,14
Program Management/ Business Tools	Positive impact across the board	All	coordination's " communication	min cost / max benefits	minimal 1,2,3,4,5,6,7,8,9,10,12,13,14
Scalability	Requirements ID at early stages	a,b,c,d,e	component portions easier to V&V	increases costs	re-credit with each build / component
1 Stability of requirements	variability of Sim1 requirements as a consequence of the inherent instability of the problems				
2 Complexity of user Requirements	#complexity of the sim requirements as a consequence of the inherent diff of the problem				
3 Security reqts	#complexity and compartmentalization of information and security required to access that info (firewalls, etc.)				
4 Time available	classification and compartmentalization of information and security required to access that info (firewalls, etc.)				
5 System docs	degree to which the system is well described in appropriate form (docs, etc.)				
6 Required Credibility	The degree of evidence needed to provide credibility of the results or the stringency of level of proof required by the Accred. Authority				
7 Net Risk	probability of risk x impact of that risk				
8 Size/complexity of Unit Under Test UUT	size & complexity of the simulation system and or components				
9 Maturity of the sim development process akin to SE/CMM but correlated to simulation development					
10 Availability of reference data	data used to compare simulation results to (e.g. validation reference data)				
11 COTS/GOTS (decision to use)	visibility or lack thereof to COTS and its inherent quality or pre-qualification to the cost of VV&A; need to develop your own (GOTS) to impact cost of VV&A				
12 competence of VV&A Execution Agents	skill and ability to execute VV&A tasks efficiently and effectively, turnover of personnel, etc.				
13 System Engineering process	quality and maturity of the entire programming management process of the referenced system (design/engineering/interfaces) of the sim development process				

Table WG 3-2 Additional Considerations

5. Key Points and Lessons Learned:

From a strategy point of view, the greatest potential cost-saving technology areas are:

- a. Program management tools and technologies appear to have a positive impact on VV&A across the board.
- b. Automated repositories. to make existing VV&A data is available in all areas and historical V&V data. This helps to reduce the research required. For example, if you have a good articulation of a model's previous usage, you may not need to do as much V&V as might be required if little is known about previous usage. There are also other implications of this item.
- c. Database technologies allow for sharing of data, provides consistency of form, format for data and help with documentation.

- d. Knowledge discovery in a database is almost uniformly positive, but may result in a need for greater security because it allows the user to aggregate data, possibly violating security requirements.
- e. Standards have a positive impact on almost all cost factors by helping to provide consistency, repeatability, conformity and aid collaboration.

From a strategy point of view, the technology areas that could benefit VV&A but also potentially have a negative impact on cost are:

- Advanced alternative representations have both a positive and negative impact on the cost of VV&A because they may be more complicated to understand and thus, more difficult to articulate credibility. By providing a high level of functionality,

these methods may reduce the size and complexity of modeling a unit under testing.

- Security technology can make it easier to distribute and share information. If done well, with the ideas of being able to share information, it may reduce cost. Security and encryption technology may limit accessibility to data, thereby increasing the cost of V&V.
- Scalability may make it easier to validate an aggregate model if component models are validated. Scalability may result in a more complex model, with the consequence that the people who do the V&V may need to be more competent in the spectrum of what is being modeled

6. Issues and Concerns

- a. The expression of cost factors, dependencies and relationships isn't well defined for M&S nor, consequently, for VV&A.
- b. The allocation cost to VV&A versus allocation to system development (as well as product quality and VV&A costs) need to be better defined and appreciated.
- c. Our evaluation and judgment of the significance of technology upon the economy VV&A is rough but suggestive.

The most effective way to address these concerns would be the establishment of an extensive database of VV&A costs for a large collection of M&S programs. Analysis of the database would help define more effective cost measures and allow for tracking productivity.

Technologies	Cost Factors													
	Schedule time available	Size/complexity of UUT	Competence of executing agents	MS documentation	Nbr/complexity of user requirements	Consistency of enterprise culture	Avail of ref data	System eng process	Probability& Impact of risk	Maturity of sim dvp process	Security requirements	Stability of requirements	Required credibility	COTS/GOTS (make or buy)
Program management tools/business practices	+	+	+	+	+	+	+	+	+	+	+	++	+	
Knowledge Discovery in Databases	+	+	+	+	+	+	+	+	+	+	-		+	+
Standards definition	+	+	+	+	+	+	+	+		+	+		+	+
Automated repositories	+	+	+		+	+	+	+	+	+	-	+	+	
Database technologies	+	+	+	+		+	+	+		+		+		+
Integrated development environments	+	+	+	+		+	+	+	+	+	+	+		
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Conceptual model forms/notation	+	+	+	+	+	+		+		+		+		
Computational capability	+	+	+	+	-		+		+		+		+	
Test generation tools	++	+	+	+	+	+	+		+	+				
Analysis/visualization tools	+	+	+	+	+	+	+	++						
Code generation tools	+	+	+	+	+			+		++				
Advanced alternative representations	-	+	-	-	-			+	+	+			-	+
Synthetic environments	+	+	+	+	+	+	+	+			+	+		
Telecom infrastructure	++	-		+	-		+					-		
High order languages	+	+	+	+		-			+					
Decision support tools	+		+		+			+	+					
Scalability	+	-	-	+	+	+			+					
Security/encryption	-	-		-			+				+			+

Table WG 3-3 Cost Factor Technology Crosswalk

7. Cost Factor — Technology Crosswalk:

Schedule time availability is the factor that appears to have the greatest potential for improvement through technology.

Improvements in technology have a significant potential for reducing cost by increasing the availability of reference data. This helps to reduce the amount of re-work needed, and helps to reduce the reliance on subject matter experts for validation.

Technology has potential for enhancing the expertise available to V&V agents.

All process-related cost factors appear to be strong candidates for application of technology, resulting in a decrease in the cost of V&V. Improved technology in these areas helps to

improve information capture and flow, e.g. automated configuration management tools.

8. Net Assessment Of Issues: The community needs to periodically reassess the technology available for reducing the cost of VV&A. Some technology areas have a potential for both decreasing and increasing the cost of VV&A. For example, advanced alternative representations, such as neural nets, may reduce the size of a model by providing a high level of functionality. However they may be more complicated to understand, making it more difficult to articulate credibility. Security technology may increase cost by limiting access to information. Practitioners need to be

particularly careful about how these will impact VV&A costs. Cost benefit analyses need to be done to show that quality improves over time.

It is not clear how to account for costs and cost avoidance of VV&A as compared with normal M&S development costs. Three different cost models are needed, on the topics of legacy, new development and distributed interactive simulations. Cost factors need to be standardized

and metrics established for VV&A from standard M&S.

One possible source of data for cost metrics is a repository recently established by the Navy. The database has templates for reporting and verification, validations, plans and reports, and is hyperlinked. (For more information, contact Bob Hartling at Chief of Naval Operations (N812D), 200 Navy Pentagon, Washington, DC 20350-2000.)

SIMVAL 99 Synthesis Group Synopsis

Synthesis Group Leaders:

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1. Background In the late 1980s, the defense community began a transition from the *mainframe era*, in which a few organizations developed and used simulations in-house, to a *workstation era*, in which those simulations were increasingly hosted on more portable platforms and exercised by organizations that were not involved in their development. As this transition occurred, the defense community also came to believe that families of simulations could provide significant cost savings for analysis, training and engineering. While such capability promised significant opportunity, it also implied a consistent separation of the simulation developer from the user. Therefore, in order to exploit this technology, the defense leadership understood that it would be necessary to establish procedures to ensure that:

- Users would have access to information and methods that would allow them to assess the appropriateness of available models
- Developers would collect and maintain appropriate information about the reliability and accuracy of their models that would support the user's needs

While the software engineering literature of the 1980s provided standards for software requirements development and analysis, it did not support two important issues: the appropriateness of real world characterization and abstraction in simulations; and, support of acceptance testing on a continuing basis (e.g. by users not involved in initial development).

To address these issues, MORS sponsored a series of activities on Simulation Validation (SIMVAL). The initial mini-symposium (SIMVAL I) in October 1990 and subsequent workshops, SIMVAL II in April 1992 and SIMVAL 94 in September 1994, provided the basis for a broad set of policies, activities and practices referred to as VV&A of simulations. SIMVAL 99: Making VV&A Effective and Affordable has provided an opportunity to assess both technological advances and the progress that has been made by the community over the intervening years.

2. Conclusion The scope of the Synthesis Group included: technology and methodology issues that are *cross-cutting* in that they have a significant impact on both V&V; and, issues that impact on the integration of VV&A.

It is the general assessment of the Synthesis Group that, notwithstanding substantial effort and goodwill, the community's capacity to implement VV&A, as envisioned in 1992, remains disappointing. Methodologies remain immature, largely ad-hoc and incomplete. Supporting technologies are not fully compatible methodologically and computationally (hardware and software). More alarmingly, the collective state of knowledge by practitioners is disappointing. The sections that follow discuss four major issues that contribute to these observations.

3. Introduction. Efficient and effective accreditation decisions are sensitive to three key elements:

- a. Large and accessible data repositories, specifically:
 - Hardware, software and network technology
 - Community standards for documentation
- b. Automated reasoning systems for analyzing appropriate data in available repositories and reducing those results to practical (useful) metrics, specifically:
 - Analytical methods
 - Software that implements those methods on automated databases / repositories
- c. Human knowledge (derived from training, study and experience) about how to effectively apply the first two capabilities

A fourth, and equally important capability for sustaining an effective VV&A program, is the capacity to capture the value of VV&A activities, collectively and individually. The community's current inability to fully define the implicit (hidden) as well as explicit costs and benefits of individual VV&A activities contributes to less than effective investments and, to some extent, a general feeling of frustration about VV&A.

If DoD is to make VV&A *Effective* and *Affordable*, it must overcome four challenges. First, integrating methodologies must be matured to ensure that the results of disparate V&V activities are synthesized into coherent metrics that users can use to understand the decision and training risks that are associated with a given model and its intended use. While powerful database technologies provide the essential

enabling technology, this is an analytical and procedural challenge.

Secondly, the community needs to develop sufficiently expressive high-level languages or formalisms that will allow SMEs, users and software engineers to communicate effectively using a CCM. This is largely a technology issue.

Third, the community must develop consistent and credible procedures, derived from a common model of cost, for assessing the value of VV&A activities, especially hidden and deferred costs.

Fourth, the defense leadership must redouble its efforts to institutionalize good practice. This challenge also applies to the non-defense community. In both instances, investments in infrastructure (repositories, networks and training) are required.

4. Synthesis Issue 1: Develop verification and validation methodologies that synthesize disparate analyses into coherent metrics that support the accreditation requirements of users.

As previously discussed, and illustrated below, the underlying motivation for DoD's VV&A policies and practices is to ensure that users can make well-informed judgements about the decision and training risks associated with simulation-based activity. While the V&V literature provide a substantial number of tools and techniques, users continue to be frustrated, in large part, because V&V reports are often difficult to understand from the user's perspective. While the implications are the same, the root causes are different for V&V.

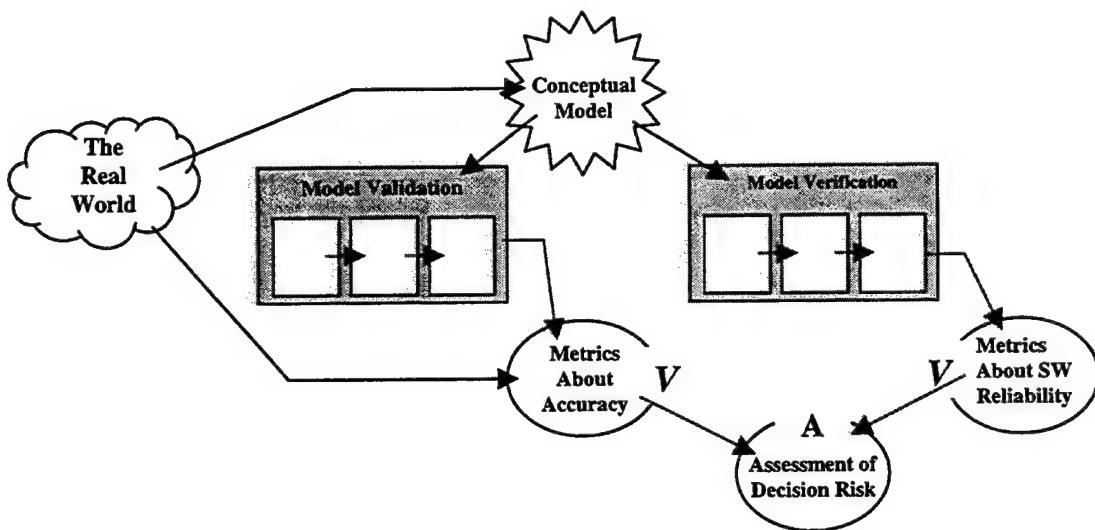


Figure SG-1 VV&A Perspectives

As a simplified model, the figure below characterizes how a user conducts validation assessment. Based on a comparison of model output and observations drawn from the real world, the validation agent produces an

assessment of the model's prediction uncertainty (likely error). This value is then compared to the user's tolerance for error (validation criteria) to make a determination about the model's suitability for the intended application.

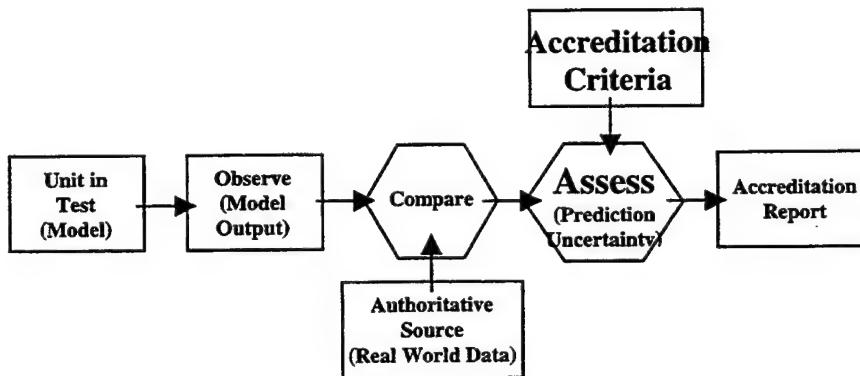


Figure SG-2 Accreditation Considerations

While the general analytical method is straightforward, the science, mathematics and statistics communities have not yet produced a truly comprehensive theory for quantifying prediction uncertainty in simulations. For that reason, the comparison step in model validation remains largely qualitative (face validation) and ad-hoc. Because of difficulties with knowledge elicitation and conceptual modeling, this practice leads to further increases in uncertainty about subjective judgements as well as increased cost. Although a comprehensive theory remains elusive, DoD continues to monitor and support the relevant research to ensure that as formal methods mature, they are incorporated into recommended practice so that the following user questions can be answered.

- To what extent does a model preserve what is known *and not known* about this domain?
- Was the underlying uncertainty in the database preserved?
- What modifications to the model would produce the most significant impact on its prediction uncertainty (relates to the user's decision risk management)?
- Are there simpler model designs that have relatively equivalent levels of prediction uncertainty (relates to the user's cost management)?

With respect to verification, while the causes are different, the implication is the same — the user community is rarely provided a comprehensive and coherent metric that characterizes the overall reliability of the computational model (hardware and software). Rather, verification reports generally provide voluminous information about independent analyses on the various software development activities (requirements, design, software development and implementation testing). While these reports are often useful for developers, they are rarely understandable, let alone useful, for the user. There are two general reasons for this: first, comprehensive methods do not currently exist; and second, software quality assurance standards are predominantly process versus product-based.

While the software engineering community has developed disciplined, and in some cases formal, methods for analyzing requirements, designs and software, these methods are independent of each

other. Because they are independent, adequate methods for analyzing across the development process are not, generally, available. More significantly, industry standards for Software Quality Assurance (SQA) such as the Software Engineering Institute's Capability Maturity Model (SEI CMM) and the International Standards Organization (ISO) standards are almost exclusively focused on assessment of the developer's process. Consequently, while these metrics provide qualitative views of the developer's processes, they do not generate the comprehensive product-specific metrics that are required by accreditation agents. Rather, the accreditation agent is typically provided a voluminous set of independent trouble reports. Given that even professional software engineers are rarely able to reduce such reports to a comprehensive assessment of risk, it is unreasonable to expect model users to do so.

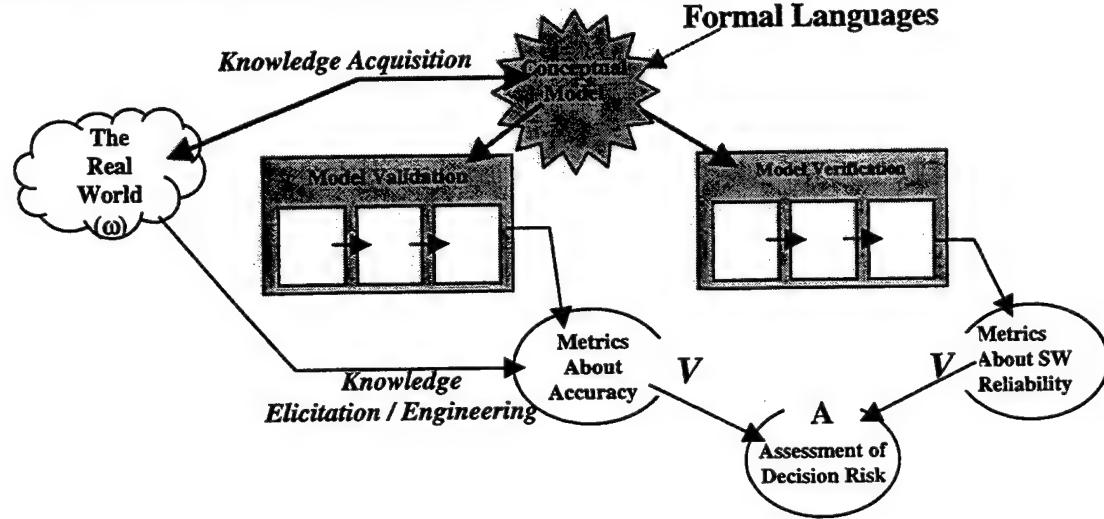
In conclusion, *user requirements for model verification are different from industry standards for SQA*. While the SQA literature provides many techniques that can be used to quantify software reliability, there is a tendency for the model development community to equate SQA practice with model verification. They are two different methods. SQA is a program management activity that is related to producing the required product on time and within budget. SQA is not an explicit VV&A task and should not be budgeted to VV&A. The software engineering community in general, and the defense M&S community in particular, needs to keep this difference in mind as a basis for reassessing standards and practices for verification reporting and costing.

5. Synthesis Issue 2: Acquire languages and technologies for developing consistent and accurate CMs.

To perform accreditation, the user must synthesize the validation agent's report about the fidelity of the model developer's representations with the verification agent's report about the reliability of the software/hardware implementation. When explicit representation of the CM is not made, it limits the extent to which structured or formal methods can be applied to requirements analysis and testing across multiple

development cycles (see the following figure). Because the costs of fixing model development problems increases non-linearly over the software

development process, the cost implications of incorrect, inconsistent, or ambiguous requirements are often substantial.



SG-3 Formal Languages

Because SME play an important role in face validation, implicit CMs significantly influence validation assessments in the current state of practice. Inconsistencies in the implicit mental models used by the SMEs conducting validation, and those generating requirements, can contribute to increased cost in model development and acceptance testing. While technologies to support Knowledge Elicitation / Acquisition (KA) and Knowledge Engineering (KE) have matured over the past 20 years, this technology has not yet been effectively applied to development of suitable CMs for requirements development and validation. It is not clear whether that is because the current technology (case tools) remains inadequate or whether tools are not being adequately integrated into the state of practice.

The software engineering community has also struggled for years to develop a sufficiently expressive and robust design language to support formal design analysis and test. The Unified Modeling Language (UML) and a broad range of object-based design tools are examples of this technology. While the technology continues to mature, and has been generally useful for some software development projects, it has not yet found wide acceptance for large-scale, spatially distributed development enterprises and environments.

In summary, CMs play a central role in accreditation because they are used to characterize both the user's understanding of the battlespace as well as the software engineer's representational requirements. Lack of a common and adequately expressive CM almost always leads to significantly increased model development and VV&A costs because of an inability to adequately manage model requirements and their design and testing implications. Although the knowledge and software engineering communities have struggled separately with the problem of building CMs to support requirements and software development, these capabilities have not been effectively applied to simulation development in the defense (and non-defense) domains. To the extent that the competitive nature of combat, as well as the dynamic characteristics of military operations, limits the utility of existing design languages, the development of a common, sufficiently expressive meta-language and supporting technologies for both domain experts and software engineers is needed. We do not believe such a capability exists. Development of such a capability could significantly reduce overall model development and VV&A costs in DoD.

6. Synthesis Issue 3: Identify and manage the value of VV&A activities

V&V activities allow the user to understand the risk of using simulation as a decision or training aid. As such, V&V activities should be undertaken only to the extent that they help the user and his/her accrediting agent quantify, understand and reduce that risk. The risk of using the simulation products inappropriately can be represented by the equation:

$$\text{Risk} = \text{Probability of Failure} * \text{Impact}$$

where *probability of failure* is a measure of the likelihood of the simulation behaving erroneously and *impact* is a measure of the importance of that failure. costs associated with simulation failures and the impacts of those failures. The total costs of a verification and validation program consist of four general components:

The costing of V&V of models and simulations does not now adequately reflect either the incurred costs of a verification and validation program, nor does it address the value of the verification and validation program in avoiding

$$\begin{aligned} \text{Total VV\&A Cost} = \\ & \text{Cost of Executing Validation} + \\ & \text{Cost of Executing Verification} + \\ & \text{Cost of the User of Being Wrong} + \\ & \text{Cost to the Developer of "cleaning up the mess"} \end{aligned}$$

where:

- Cost of executing validation includes all costs directly incurred to support validation activities
- Cost of executing verification includes all costs directly incurred to support verification activities excluding those costs to produce products in simulation development that are a normal part of good software engineering practice

The remaining two factors in the equation share the characteristic that the amount decreases as the effectiveness of the V&V program improves:

- Cost to the user of being wrong includes costs incurred because an incorrect decision (based on simulation results) was made and implemented. It could include such costs as the cost of correcting negative training, or the costs of a false start on the next phase of an acquisition program, or the cost to redo a simulation based experiment once the failure is discovered and corrected
- Cost to the developer of "cleaning up the mess" includes all costs needed to change the simulation software in order to allow the production of better results (defect correction costs).

The allocation of resources between V&V activities should be based upon the impacts identified. For example, if a simulation requires a heavy investment in operator resources (salaries, travel, etc.) then verification of the mean times between failures and mean times to repair may have greater impact on success than validating the nuances of degrees of faithfulness of the simulation to the simulated system. On the other hand, use of simulation to support a milestone decision in simulation-based acquisition may dictate that more attention be paid to the correctness and faithfulness of simulation results than to the strict adherence to best software engineering practice.

An important, albeit often overlooked, aspect of model validation is the reference data — the real world observations to which the intermediate or final outputs of the simulation are compared. Furthermore, because a model can be no more accurate than the underlying data (that which served to generate the embedded abstractions (algorithms), investments in data collection are a critical component in model fidelity. Because of their relatively high costs, however, live testing and experimentation are often difficult to justify. For that reason, it is important to understand the value of data collection activities relative to model user requirements for fidelity. As an example, measurement records on the flight path of a target, as well as the trajectory of an engaging weapon, can only be as precise as the test instrumentation and data collection procedure (sampling) used in the experiment. Reduced fidelity in data collection contributes to variability

in test data. Sometimes this variance changes in its level of importance to a user of this data. In summary, there is a direct relationship between investment in data collection and the costs of being wrong. This tradeoff analysis is an important, albeit often overlooked, aspect of managing a credible VV&A program.

7. Synthesis Issue 4: Develop a mature and robust state of practice

One of the critical observations of SIMVAL 99 is that the V&V community remains largely ill-informed about the availability and applicability of tools which may support the V&V process. This has serious implications to the practice of V&V. With respect to the *current state of practice*, we believe that:

- The available methodologies are still not well-understood
- There is only rudimentary familiarity with available tools and their applicability
- Comprehensive sources of information on tools as well as their applicability (case studies) are not available
- There is little available information about V&V cost implications from either the developer or the user's perspective.

Failure to address these problems will likely lead to a future with:

- Lots of talk about process, but little progress for users

Limited support to reuse opportunities — information in multiple, diverse formats;

- A general inability to implement efficient V&V, especially for large simulations
- Difficulty in justifying investments in V&V
- A continuation, if not institutionalization, of the view that VV&A is too costly and too hard

In order to effect change and improve the state of practice, it is imperative that the community:

- Build a compelling base of knowledge through a strong education curriculum
- Improve access to information — build essential and accessible databases
- Build a methodological framework that supports the effective application of automated tools
- Publish case studies
- Develop, document and disseminate cost-impact information to demonstrate the value of tools and procedures.

Conclusion

The SIMVAL 99 Workshop tackled a difficult problem and made good progress, as indicated by the contents of this report. This success was made possible by the talent and dedication of its participants. The challenge is now before the MORS Sponsors and the SCS International leadership to lend their support to the SIMVAL 99 recommendations, both the general ones presented early in the body of this report and the more detailed ones contained in the group synopses, so that maximum benefit may accrue to the M&S communities inside and outside DoD.

1. SIMVAL 99 Sponsorship

The initial collaborative venture between MORS and SCS International in co-sponsoring SIMVAL 99 was facilitated by involvement of a number of leaders from each organization. In addition to a

significant number of SIMVAL 99 participants who participate in both MORS activities and SCS International conferences, this involvement included:

- a. The SIMVAL 99 Co-chairs currently hold or have held leadership roles in MORS and SCS International. Those roles include MORS Director, Workshop Chair, MORS Symposium WG Chair, membership on various MORS Senior Advisor Groups (SAGs), SCS Director, Associate Editor for Validation of the SCS journal (*Simulation*), and General Chair, Program Chair, and Session Chair for SCS conferences.
- b. Other significant leaders from MORS and SCS International

From MORS:

Natalie Addison	Vice President (Administration)
Dennis Baer	President
Alfred Brandstein	Director
Paul Davis	Wanner Laureate
CAPT Lawrence Dick	Vice President (Professional Affairs)
CAPT Robert Eberth	Director
Christine Fossett, FS	Past President, Fellow
Col Kenneth Konwin	Director
Cynthia Kee-LaFreniere	Assistant Administrator
Corrina Ross	Communications Manager
Robert Sheldon	President Elect
Clayton Thomas, FS	Past President, Wanner Laureate, Fellow, Sponsor's Representative (USAF)
E. B. Vandiver III, FS	Past President, Wanner Laureate, Fellow
Richard Wiles	Executive Vice President

From SCS International:

Osman Balci	Director at Large, SCS Representative to Board of Winter Simulation Conference
Bruce Fairchild	Senior Vice President
William Waite	Director at Large, SCS Representative to MORS

2. SIMVAL 99 Products

By the time this report had been completed (mid-February), an article based upon SIMVAL 99 had

been prepared for publication in *PHALANX*, briefings based upon SIMVAL 99 had been presented to the DMSS VV&A Technical Support Team (the TST is preparing the revision of the

DoD VV&A RPG) and the DMSO VV&A Technical Working Group (TWG), a briefing about SIMVAL 99 prepared for the MORS Sponsors, and arrangements made for SIMVAL 99 briefings at the March 1999 Simulation Interoperability Workshop (SIW), the June 1999

MORS Symposium, and the July 1999 Summer Computer Simulation Conference (SCSC). In addition, a plenary luncheon talk on V&V Technology at the 1999 SCSC is planned as is a SIMVAL 99 article for *Simulation*.

Appendix A
TERMS OF REFERENCE (TOR)*

MILITARY OPERATIONS RESEARCH SOCIETY (MORS)
SIMULATION VALIDATION (SIMVAL) WORKSHOP 99
Making VV&A Effective AND Affordable
26-29 JANUARY 1999

SIMVAL Workshop 99 is co-sponsored by the
Society for Computer Simulation International (SCSI)

Background

Since the late 1980s, MORS has led conceptual development for simulation validation (SIMVAL). Since the last SIMVAL workshop (held in 1994), Verification, Validation, and Accreditation (VV&A) have become central themes in DoD modeling and simulation. DoD Instruction 5000.61 was released in April 1996 to set policy guidance for VV&A. The DoD VV&A Recommended Practices Guide (RPG), published in November 1996, is a leading source of VV&A guidance within DoD today. Efforts are underway to improve the RPG, incorporating lessons learned from those who have followed its guidance. Significant increases in formal VV&A activity within DoD organizations have also been noted.

These developments underscore the need for advancing the state-of-the-art in VV&A. Decision makers, program managers, simulation developers, V&V practitioners, VV&A agents, V&V theorists, academia, and simulation users are all concerned with the conduct of VV&A. While DoD has moved forward in the areas of policy and procedure, other salient needs have yet to be met. Most notably, the full scope of current VV&A *technologies* need to be identified and related to the needs of DoD organizations. Such exposure of VV&A technologies should include not only tools and methodologies for performing V&V, but should also address *costs* associated with conducting VV&A – and should especially identify those technologies which can increase V&V effectiveness without increasing costs or decrease costs without degrading V&V effectiveness. VV&A technologies and methodologies have pertinence for those outside DoD as well as for those within the Defense community. MORS welcomes the co-sponsorship of SIMVAL Workshop 99 by the Society for Computer Simulation International (SCSI), an organization that has served simulation professionals since the 1950s, and which will facilitate involvement in this workshop by those outside the Defense community.

Objectives

The SIMVAL 99 Workshop, *Making VV&A Effective AND Affordable*, will explore how to ensure M&S correctness and credibility in effective, efficient, and affordable ways. The

* This final version of the TOR identifies actual leaders of the SIMVAL 99 Working Groups and Synthesis Groups (various circumstances, such as unanticipated schedule conflicts, forced a few changes from those identified earlier), adds a few items to the recommended reading, updates some of the plenary session descriptions, and deletes the workshop application form and related materials.

SIMVAL 99 Workshop is open to both US and non-US participants. It will examine current *technology* supporting VV&A and identify promising areas of possible technology developments that can enhance VV&A. Such enhancements may be achieved by making VV&A more effective for a given level of resources or by allowing the same level of VV&A to be achieved with reduced resources. The three specific areas that the workshop will focus on are 1) verification technology, 2) validation technology and methodology, and 3) the impact of technology on VV&A costs. Although some of the topics within these three areas are still being developed within the DoD M&S community and elsewhere (such as the topic of simulation fidelity), the SIMVAL 99 Workshop will maintain its focus on VV&A *technology* and not attempt to solve such related issues. The SIMVAL 99 Workshop will simply use concepts that currently exist in such areas as the Workshop explores ways in which technology can enhance or advance VV&A capabilities. The emphasis of the SIMVAL 99 Workshop is on VV&A technology, but this emphasis is in the context of making models and simulations more useful and effective in operations research and analysis.

Agenda

Day 1 am: The agenda for this three day unclassified workshop will start with a plenary keynote session on the morning of the first day. The plenary session, which will be open to a larger group than those who participate in the full SIMVAL 99 Workshop, will have four parts:

1. The Workshop Chairs will welcome the workshop participants and provide a short introduction and overview of the SIMVAL subject area. This overview will include a summary of issues and concerns, the workshop's objectives, and the agenda. SIMVAL issues identified during previous MORS special meetings, specifically ADSA 96 and Complexity in Modeling and Simulation-Linkages, will be addressed in relation to the focus of this workshop.
2. CAPT Dennis McBride, Office of Naval Research, Program Manager for Medical S&T has agreed to be the keynote speaker for SIMVAL 99. The keynote address will provide a broad context for simulation validation and set a series of specific challenges before the participants.
3. A review of V&V technology will be conducted to calibrate the participants about current technology capabilities. This material will also be included as part of the read-ahead materials. Mr. Robert Poston, Aonix, was scheduled to conduct the review, but was prevented from attending SIMVAL 99 by illness in his family. Col Kenneth Konwin, Director of the Defense Modeling and Simulation Office (DMSO), served as a surrogate for Mr. Poston with a V&V technology review presentation during the keynote plenary session.
4. Dr. Paul Davis of RAND will offer a cautionary perspective on VV&A, noting issues of research base, bureaucratic mischief that impedes high-quality analysis, and opposing trends in commercial off-the-shelf software, some of which help and some

of which hurt the cause of VV&A. He will end with some suggested principles for VV&A related tools, illustrating some of the points with examples from recent work.

Note: Those who participate in the opening plenary session (but not in the entire workshop) will be able to interact with SIMVAL 99 participants during the afternoon break and mixer of Day 1. Some in this category are expected to be developers of V&V tools who want to be available to provide additional information about their tools to SIMVAL 99 participants. Space will be provided for small displays and additional materials about V&V tools beyond that which is provided in the SIMVAL 99 read-ahead packages and workshop handouts.

Day 1 pm and Day 2 am: After the plenary session, SIMVAL 99 Workshop participants will break into working groups for the remainder of the first day and for the morning of the second day to focus on specific issue areas indicated below. A mixer will be held on the first day during the late afternoon. Developers of V&V technology may be available during the afternoon of the first day to provide additional information about their technologies. The read-ahead package will also include descriptive information about various V&V technologies, including V&V automation tool descriptions in a common format (more information about this may be found at the end of this TOR). Members of the Synthesis Group will participate in the Working Groups to facilitate idea flow across the working groups.

Day 2 pm & Day 3: Each working group will outbrief on the afternoon of the second day, allowing a draft synopsis of ideas that have been formulated across the working groups. Working groups will re-form on the morning of the third day to refine and modify their ideas in light of the draft synopsis. Each working group will provide a final outbrief on the afternoon of the third day. This session will include a short summary of the issues, concerns, and recommendations identified by the workshop participants.

Day 4 am: Working Group Co-Chairs and Working Group Reporters will be part of a Synthesis Group that will meet on the morning of the fourth day to finalize the draft of the workshop report.

Working Groups and Synthesis Group

Working Group 1: Verification Technology, to include automated requirements/specification-testing and CASE tools, as they are used in the context of modern simulation paradigms (object oriented based simulation, distributed simulation, extensive use of AI and other adaptive methodologies, etc.). A subset of verification technology are descriptive formats and how such interact (e.g., this is where data/meta-data issues would reside). The emphasis of this Working Group is on the identification of available tools and their applicability, especially to military uses of M&S.

Working Group 2: Validation Technology and Methodology will focus on applications of technology to support:

- f. Subject Matter Expert (SME) selection, orientation, management, use, etc., especially in conceptual validation processes (but also in results validation)
- g. Correlation of representational fidelity with application needs
- h. Criteria for establishing needed levels of simulation fidelity
- i. Automation/technology potential (e.g., animation) to support validation methodology
- j. Correlation among the various levels of simulation CMs (CMMS, simulation concept, simulation elements/sub-elements)

Working Group 3: Impact of Technology on VV&A Costs, including identification of VV&A cost elements, costing algorithms, and rules-of-thumb.

Synthesis Group:Provide a mechanism to ensure cross-fertilization of ideas among the working groups, and to integrate and synthesize ideas from the workshop. Members of the Synthesis Group will also participate in the Working Groups as a means of facilitating this conceptual synthesis and integration.

Products

In addition to insights gained by SIMVAL 99 participants, the primary product of the workshop will be a report of the state-of-the-art in simulation VV&A technology and methodology. Current issues, concerns, and recommendations will be identified. The report will be produced by the following actions:

1. Each pair of Working Group Co-Chairs, in conjunction with their Working Group Reporter, will produce a short summary document. This document will include the following items and will be submitted **prior to departure** from the workshop.
 - a. Purpose of the working group
 - b. Membership of the working group
 - c. Synopsis of the discussion's key points and lessons learned
 - d. Significant issues, concerns, and recommended solutions
 - e. Smooth copies of all visual materials (in both hard and soft copy)
2. **Prior to departure** from the workshop, the Synthesis Group, in conjunction with the SIMVAL 99 Workshop Chairs, will review and integrate the working group reports. They will draft a workshop summary and an integrated list of issues, concerns, and recommendations.

The SIMVAL 99 Workshop Chairs will submit a report of the workshop to the MORS office in paper and electronic form no later than 30 days after the workshop ends. That report will draw upon the materials described above and contain one or more articles about the workshop suitable for future publication in *PHALANX*, *SIMULATION*, and elsewhere. The SIMVAL 99 Workshop Chairs will also prepare a briefing package for presentation to the MORS Sponsors and at the next Symposium. An appropriate paper, based upon findings of the workshop, will be prepared for one or more future SCSI conferences.

Workshop Organization Structure

The SIMVAL 99 Workshop Co-chairs will be Mrs. Priscilla A. Glasow, The MITRE Corporation, and Dr. Dale Pace, Johns Hopkins University Applied Physics Laboratory. The Workshop Co-chairs will control the attendance so that it falls in the range of 120-150 full participants – there will not be a restriction on the limited participation. Active use will be made both of members of appropriate MORS working groups and of contacts with V&V leaders from outside MORS, especially those within the SCS International community, to ensure that participants in the Workshop have the requisite expertise to ensure that the Workshop can accomplish its objectives.

Two Co-Chairs and a Working Group Reporter will lead each Working Group. The Working Group Co-Chairs will be responsible for organizing and leading the working group as well as for moderating discussions and will take responsibility for participating in the final workshop synthesis session on the morning of the fourth day. Working Group Co-Chairs, in coordination with the SIMVAL 99 Co-Chairs, may recruit specific individuals to be part of their working group in order to ensure that requisite expertise exists in the group. Working Group Reporters are responsible for recording the discussion of their respective working groups, noting particularly the lessons learned, issues, concerns, and recommendations of the participants. Working Group Reporters are also invited to the final workshop synthesis session on the morning of the fourth day.

The Working Group Co-chairs and Reporters are:

1. Verification Technology

Co-Chairs:

Robert O. Lewis (Tec-Masters, Inc.)

Osman Balci (Virginia Tech)

Reporter: Susan Solick (TRAC)

2. Validation Technology and Methodology

Co-Chairs:

Gary Coe (IDA)

Tom Ruth (AMSAA)

Reporter: Dennis Laack (CSC)

3. VV&A Costs

Co-Chairs:

Richard Kuhn (NIST)

Bill Waite (Aegis Research)

Reporter: William Jordan (SMDC)

Synthesis Group

Co-Chairs:

Simone Youngblood (DMSO-JHU/APL)

John Morrison (LANL)
Reporter: Walt Stanley (TRW)

Attendance at SIMVAL 99 will be by specific invitation from the Workshop Co-Chairs. Those invited will be selected from those who have completed a request for participation in the workshop (a copy of the request for participation form is contained at the end of the TOR). Priority for full participation in SIMVAL 99 will be given to those who (1) have current experience and knowledge of verification and validation technologies and methods, (2) have experience or insight related to VV&A costs, or (3) have near-term simulation VV&A concerns and issues.

Schedule and Fees

The workshop will be held at the Kossiakoff Conference Center of Johns Hopkins University/Applied Physics Laboratory (Laurel, Maryland) on 26-29 January 1999 (see the JHU/APL website for directions: URL = <http://www.jhuapl.edu/public/visit/locat.htm>).

For full participation in SIMVAL 99, the fee will be \$180 for federal government employees and \$360 for all others.

For limited participation (this is participation in the opening plenary session and the Day 1 afternoon break and mixer), the fee will be \$75 for federal government employees and \$150 for all others.

MORS will handle registration and financial arrangements.

Military Operations Research Society (MORS)
101 S. Whiting Street, Suite 202
Alexandria, VA 22304-3416
(703) 751-7290 / (703) 751-8171 (FAX)
email: morsoffice@aol.com

Suggested Reading:

Volume 9 Modeling and Simulation, Technology for the United States Navy and Marine Corps 2000-2035: Becoming a 21st-Century Force, report of the Panel on Modeling and Simulation, Committee on Technology for Future Naval Forces, Naval Studies Board, Commission on Physical Sciences, Mathematics, and Applications, National Research Council. Published by National Academy Press (Washington, DC), 1997.

Robert M. Poston, *Automating Specification-Based Software Testing*, IEEE Computer Society Press, 1996. ISBN: 0-8186-7531-4.

Pertinent contemporary VV&A-related papers and articles may be found in the proceedings of recent Simulation Interoperability Workshops (SIWs) – these can be downloaded from the SIW

website (URL = <http://www.sisostds.org/siw/>), in the proceedings of the summer and winter conferences of the Society for Computer Simulation International (SCSI) -- check its website for more information (URL = <http://www.scs.org>), and in the September 1996, March 1997, and June 1997 issues of MORS *PHALANX*.

Some may find the VV&A chapter of the recently published text, *Applied Modeling and Simulation: An Integrated Approach to Development and Operation* (D. J. Cloud and L. B. Rainey, eds, McGraw-Hill, 1998, ISBN: 0-07-228303-3) to be helpful.

Orientation to formal methods, their costs-benefit, and associated automation may be found in Volume 1 of NASA-GB-002-95 (Release 1.0), *Formal Methods Specification and Verification Guidebook for Software and Computer Systems*, July 1995, NASA Office of Safety and Mission Assurance. This document itself (as well as Volume 2 which contains more detailed information) can be downloaded from a NASA website about Formal Methods website. Its URL is: http://eis.jpl.nasa.gov/quality/Formal_Methods/index.html . The more general website (drop the "index.html") includes a number of useful links to other websites about formal methods.

Jim Van Buren and David A. Cook, "Experiences in the Adoption of Requirements Engineering Technologies," *Crosstalk* (The Journal of Defense Software Engineering), Volume 11 Number 12 (December 1998), pp. 3-10. The URL for *Crosstalk* On-Line is:

<http://www.stsc.hill.af.mil/Crosstalk/crostalk.html>

Of possible interest also is the following. Air Force Studies and Analyses Agency (AFSAA) sponsored an accreditation support methodology for THUNDER, with links to DoD VV&A and AF VV&A web sites. You can access this via AFSAA's home page www.afsaa.hq.af.mil Path from the AFSAA's home page is "Links" / "OTHER AREAS OF INTEREST" /"Verification, Validation and Accreditation (VV&A) Support for THUNDER Campaign Simulation"

In addition to its contents, other recommended reading materials will be identified in the SIMVAL 99 read-ahead materials and handout package. SIMVAL 99 participants are encouraged to review as much of these recommended materials as they can so that the workshop may make maximum progress.

Vitas of SIMVAL 99 Co-chairs and Speakers Scheduled for the Opening Plenary Session

Mrs. Priscilla A. Glasow, The MITRE Corporation, is one of DoD's leading experts in Verification, Validation and Accreditation (VV&A). She is a Co-chair of the MORS Simulation Validation (SIMVAL) workshop and a member of the MORS Board of Directors. She is also a member of the MORS Modeling and Simulation Senior Advisory Group. Mrs. Glasow began her work in VV&A while on active duty and upon retirement from the U.S. Navy, became the first VV&A program manager for the Defense Modeling and Simulation Office (DMSO). She coordinated DoD's VV&A policy (DoD Instruction 5000.61) and was Editor and co-author of the DoD VV&A Recommended Practices Guide. Mrs. Glasow currently serves as the Lead Integrating Agent for Test and Evaluation/Verification and Validation for the Joint Warfare System (JWARS). She is a member of the DMSO VV&A Technical Support Team and the VV&A Technical Working Group. She is a member of the Wargame 2000 IV&V team and supports a variety of BMDO programs. Mrs. Glasow is a contributing and active member of numerous professional organizations including the Institute for Operations Research and the Management Sciences

(INFORMS), the International Test and Evaluation Association (ITEA), the American Defense Preparedness Association (ADPA), and the Society for Computer Simulation (SCS).

Dr. Dale K. Pace, a member of the Principal Professional Staff of The Johns Hopkins University Applied Physics Laboratory, is a specialist in operations research, modeling and simulation, analysis, and wargaming. He taught in the Hopkins graduate program in technical management and at the Naval War College, where he developed an elective course on technology and naval warfare. Dr. Pace is co-chair of the Military Operations Research Society (MORS) Simulation Validation (SIMVAL) Workshop, a member of the Defense Modeling and Simulation Office (DMSO) Verification, Validation, and Accreditation (VV&A) Technical Working Group, one of the original co-chairs of the Distributed Interactive Simulation (DIS) Workshop's VV&A Group, and an initial members of the Simulation Interoperability Standards Organization (SISO) Simulation Interoperability Workshop (SIW) Conference Committee. He leads the validation part of the independent verification and validation (IV&V) team for Wargame 2000 (WG2K). He is *Simulation*'s Associate Editor for Validation and was Program Chair and General Chair for the Society for Computer Simulation (SCS) summer conferences in 1991 and 1994 respectively.

Captain Dennis McBride is Research Area Manager for Biomedical Science and Technology at the Navy Medical Research and Development Command. This organization is currently transforming and is functioning as the Medical Systems Division at the Office of Naval Research. Following graduation from Navy Flight Surgeon School and Navy primary flight training, Captain McBride was designated a Naval Aerospace Experimental Psychologist. He has since served at five Navy laboratories, principally in R&D and flight test of tactical aircraft and systems, as science advisor to the Deputy Assistant Secretary of the Navy (C4I), and as Program Manager for modeling and simulation at the Defense Advanced Research Projects Agency. Captain McBride organized and managed the DARPA programs in computer-generated forces, intelligent gateways, and synthetic environments that were ultimately demonstrated as the Synthetic Theatre of War ACTD. Dr. McBride graduated from the Navy flight test engineering training program and was selected by the Navy as a NASA astronaut candidate. His academic background includes five advanced degrees including the Ph.D. in mathematical learning theory, masters' degrees in systems, public administration, and experimental psychology, and a second Ph.D. in the sociobiology of economics (1998). Captain McBride has published and presented more than 100 scientific papers in the fields of experimental and engineering psychology, aeromedicine, information technology, economics and political science, sociobiology, and flight test engineering. He is an adjunct professor at the Krasnow Institute for Advanced Study where his research interests are concentrated on modeling complex adaptive systems. Military decorations include the Defense Superior Service, Meritorious Service, and Joint Service Commendation Medals, and he was presented the L.P. Coombes medal for technological contributions in 1992.

Mr. Robert M. Poston of Aonix (New Jersey office) has invented and marketed software tools, participated on software testing research projects, and led national and international standards efforts. He has written more than sixty articles about software quality and testing, and served as a charter member of the editorial board of *IEEE Software*. During his career, he managed operations of NASA's Western Test Range at Vandenberg Air Force Base (CA) where he directed the work of 750 people preparing for missile launches. He headed software projects on the Trident submarine while working for RCA. He founded and presided for 12 years over a small company called Programming Environments.

Dr. Paul Davis has a B.S. from the University of Michigan and a PhD in theoretical chemical physics from MIT. Dr. Davis worked subsequently at: the Institute for Defense Analyses (IDA) on strategic technology; at the U.S. Arms Control Agency on SALT II and space issues; at the Office of the Secretary of Defense (Program Analyses and Evaluation) as a strategic analyst and, as a senior executive, on a combination of strategy and programs that underlay creation of USCENTCOM and the capabilities demonstrated in Desert Shield; and at RAND, where he has worked on strategic and defense planning, advanced modeling and simulation, decision modeling, and theories of deterrence. He was editor and principal author of a 1994 book "New Challenges for Defense Planning," that emphasized "capabilities based planning" and planning for adaptiveness. He has written extensively on the theory and practice of multiresolution (variable-resolution) modeling. As the architect of the RAND Strategy Assessment System (RSAS) for global, theater, and operational-level analytic war gaming, he has been a major proponent and practitioner of methods for planning under uncertainty. Dr. Davis wrote a widely circulated study for DMSO on VV&A (reprinted in the MORS volume on the subject) and has briefed extensively on methods and technologies to improve VV&A.

Dr. Davis has served tours at RAND as a program director and corporate research manager. He currently devotes full time to research, primarily on special cross-cutting projects.

Appendix B Agenda

January 26th (Tuesday):

0730 on: Registration

0830-1200: Plenary Keynote Session

SIMVAL 99 Welcome (Dr. Dale Pace, SIMVAL 99 Co-Chair)

Host Facility Welcome (Dr. James Coolahan, JHU/APL Asst Director for Modeling & Simulation)

MORS Welcome (Mr. Denny Baer, MORS President)

SCSI Welcome

SIMVAL 99 Introduction & Overview (Mrs. Priscilla Glasow, SIMVAL 99 Co-Chair)

- summary of issues and concerns,

- workshop objectives

- introduction of Working Group and Synthesis Group leaders

Keynote Address (CAPT Dennis McBride, Office of Naval Research, Program Manager for Medical S&T)

Break

Review of V&V Technology (Col Kenneth Konwin, surrogate for Mr. Robert Poston, Aonix)

A Cautionary Perspective (Dr. Paul Davis, RAND)

SIMVAL 99 Instructions (Dr. Dale Pace, SIMVAL 99 Co-Chair)

- handout materials

- tool displays

- Working Group and Synthesis Group rooms & schedule

- Working Group assignments

1200-1300: Lunch

1300-1530: Individual Working Group Meetings (Session A)

1600-1700: General Session (verbal reports from Working Group leaders) – in Auditorium

1700-1900: SIMVAL 99 Mixer

Note: Exhibits of V&V technology and tools were available for inspection/discussion on Tuesday.

January 27th (Wednesday):

0730 on: Registration

0830-1200: Individual Working Group Meetings (Session B) – breaks as needed

1200-1300: Lunch

1300-1530: Individual Working Group Meetings (Session C)

1530-1600: Break

1600-1700: General Session (verbal reports from Working Group leaders) – in Auditorium

January 28th (Thursday):

0730 on: Registration

0830-1200: Individual Working Group Meetings (Session D) – breaks as needed

1200-1300: Lunch

1300-1530: Individual Working Group Meetings (Session E)

1400-1430: Break

1430-1700: Final Session (Reports from Working Group leaders) – in Auditorium

January 29th (Friday):

0830-1230: Wrap-up Session (Working Group Leaders & Synthesis Group only)

Appendix C

Participants and V&V Tool Surveys/Exhibits

The appendix begins with the SIMVAL 99 V&V tool surveys and identification of those which were exhibited at SIMVAL 99. The appendix then identifies participants in SIMVAL 99.

VV&A Technology & Tool Surveys and Related SIMVAL 99 Exhibits

There were six responses to the SIMVAL V&V tool survey. They are named below. The two page V&V tool survey response forms for these tools are contained at the end of this appendix. The items below that are listed in ***bold italics*** had an exhibit table at SIMVAL 99.

- Accreditation Support Site
- ***Data Verification Interactive editor (DAVIE)***
- ***Evaluation Environment***
- ***JWARS V&V Database***
- ***McCabe Visual Testing Toolset***
- PerfMETRICS

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SIMVAL 99 M&S V&V Tool Survey Responses

The SIMVAL 99 TOR version used to announce the workshop requested standardized descriptions of V&V tools and provided a survey form by which to collect such tool descriptions. The responses to this M&S V&V tool survey are contained in this part of the SIMVAL report. Tools reported are identified below and the survey responses about them follow.

- Accreditation Support Site
- Data Verification Interactive editor (DAVIE)
- Evaluation Environment
- JWARS V&V Database
- McCabe Visual Testing Toolset
- PerfMETRICS

SIMVAL 99 M&S V&V Tool Survey Form

This form is designed to collect information about M&S V&V automation capabilities. The information obtained by responses to this survey will be provided to all participants in SIMVAL 99. Those who provide information via this form will be provided an opportunity to have additional information about their tools available for SIMVAL 99 participants (as described in the note at the end of this form). **Restrict response to fit on form.**

Tool Name: Accreditation Support Site

Developer/Provider/POC [name & contact information of individual(s) and/or organization]:

S³I - Millard Barger - 703-684-8268 or millard@s3i.com

Brief description of primary use(s) for the tool & what issues it is intended to address:

Accreditation support via the internet supplying information about a given model or simulation. Information is organized to reflect and support accreditation requirements.

Simulation Phases For Which the Tool Is Applicable (please check all which apply):

<input type="checkbox"/> M&S Planning (include resource estimation)	<input type="checkbox"/> M&S Configuration Management
<input type="checkbox"/> M&S Requirements	<input type="checkbox"/> M&S Use/Application & Maintenance
<input type="checkbox"/> M&S Conceptual Modeling	<input checked="" type="checkbox"/> M&S Assessment/Evaluation
<input type="checkbox"/> M&S Design	<input type="checkbox"/> M&S Interoperability/Compatibility
<input type="checkbox"/> M&S Implementation	<input type="checkbox"/> M&S Modification
<input type="checkbox"/> M&S Testing & Integration	<input type="checkbox"/> V&V Planning (include resource estimation)
<input type="checkbox"/> Unit	<input checked="" type="checkbox"/> V&V Documentation/Reporting
<input type="checkbox"/> Function	<input type="checkbox"/> V&V Management
<input type="checkbox"/> Sub-system	<input checked="" type="checkbox"/> Accreditation/Certification
<input type="checkbox"/> System	<input type="checkbox"/> Standards Compliance
	<input type="checkbox"/> Other (specify):

Simulation Environments For Which the Tool Is Applicable (please check all which apply):

Simulation Variety:

- Closed Form
- Continuous
- Discrete Event
- Real-Time
- Human/System/Hardware-in-loop
- Distributed processing
- Distributed simulation
- Other (specify):

Development Environment:

- Structured
- Object-oriented
- Formal system
- "Water Fall"
- Evolutionary/Spiral
- Rapid Prototyping
- Other (specify):

Software Language(s) Which the Tool Accommodates

Please continue as appropriate (use end note for material beyond this page).

SIMVAL 99 M&S V&V Tool Survey Form (page 2) for (Tool Name):

Simulation Aspects For Which the Tool Is Applicable (please check all which apply):

<input type="checkbox"/> Architecture	<input type="checkbox"/> Algorithms
<input type="checkbox"/> Data	<input type="checkbox"/> Behaviors
<input type="checkbox"/> Collection	<input type="checkbox"/> Prototypes
<input type="checkbox"/> Reduction	<input checked="" type="checkbox"/> Management
<input type="checkbox"/> System/Component Interfaces	<input type="checkbox"/> Test Planning/Execution
<input type="checkbox"/> Human Interfaces (e. g., GUIs)	<input type="checkbox"/> Results Evaluation
	<input type="checkbox"/> Other (specify)

Tool Use Considerations: What special equipment (host computer, operating system, network, configuration, etc.)/application software/facilities/skills are required for effective use of the tool?

PC internet access.

What training is required (length and where available) for personnel using the tool?

What is the cost of the tool?

What M&S or kinds of M&S have used this tool previously?

Other Information About the Tool (references describing it, methods/metrics employed, any special relationship between this tool and CASE tools or other software development/testing automation, etc.) – use end note for material that causes the disclaimer to move to the next page:

The current implementation of this tool is for the Air Force analytic campaign simulation, THUNDER. The tool is accessible via the AFMSRR as well as the AFSAA home page. Future use is for the Office of Aerospace Studies (USAF) for the CFAM model.

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SIMVAL 99 M&S V&V Tool Survey Form

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Tool Name: Data Verification Interactive Editor (DAVIE)

Developer/Provider/POC [name & contact information of individual(s) and/or organization]:

DMSO Data Engineering
1901 N. Beauregard St. S-500
Alexandria, VA 22311

Bob Senko
503-324-0607
rsenko@msb.dmso.mil

Brief description of primary use(s) for the tool & what issues it is intended to address:

PC-based (Windows) data quality checking tool. Checks accuracy, completeness, etc. of data bases. Based on user-designed rules. Operates on any ODBC-compliant DB.

Simulation Phases For Which the Tool Is Applicable (please check all which apply):

<input type="checkbox"/> M&S Planning (include resource estimation)	<input type="checkbox"/> M&S Configuration Management
<input type="checkbox"/> M&S Requirements	<input checked="" type="checkbox"/> M&S Use/Application & Maintenance
<input type="checkbox"/> M&S Conceptual Modeling	<input type="checkbox"/> M&S Assessment/Evaluation
<input checked="" type="checkbox"/> M&S Design	<input checked="" type="checkbox"/> M&S Interoperability/Compatibility
<input type="checkbox"/> M&S Implementation	<input type="checkbox"/> M&S Modification
<input checked="" type="checkbox"/> M&S Testing & Integration	<input type="checkbox"/> V&V Planning (include resource estimation)
<input type="checkbox"/> Unit	<input checked="" type="checkbox"/> V&V Documentation/Reporting
<input type="checkbox"/> Function	<input type="checkbox"/> V&V Management
<input type="checkbox"/> Sub-system	<input type="checkbox"/> Accreditation/Certification
<input type="checkbox"/> System	<input checked="" type="checkbox"/> Standards Compliance
	<input type="checkbox"/> Other (specify):

Simulation Environments For Which the Tool Is Applicable (please check all which apply):

Simulation Variety:

- Closed Form
- Continuous
- Discrete Event
- Real-Time
- Human/System/Hardware-in-loop
- Distributed processing
- Distributed simulation
- Other (specify):

Development Environment:

- Structured
- Object-oriented
- Formal system
- "Water Fall"
- Evolutionary/Spiral
- Rapid Prototyping
- Other (specify):

Software Language(s) Which the Tool Accommodates

Please continue as appropriate (use end note for material beyond this page).

SIMVAL 99 M&S V&V Tool Survey Form (page 2) for (Tool Name):

Simulation Aspects For Which the Tool Is Applicable (please check all which apply):

Architecture
 Data
 Collection
 Reduction
 System/Component Interfaces
 Human Interfaces (e. g., GUIs)

Algorithms
 Behaviors
 Prototypes
 Management
 Test Planning/Execution
 Results Evaluation
 Other (specify)

Tool Use Considerations: What special equipment (host computer, operating system, network, configuration, etc.)/application software/facilities/skills are required for effective use of the tool?

Personal computer, P-II, Windows 95/NT, 40 MB free disk
Requires SQL anywhere or interface to DB language

What training is required (length and where available) for personnel using the tool?

N/A. Excellent User's Manual and online support.

What is the cost of the tool?

Free

What M&S or kinds of M&S have used this tool previously?

New capability. Being integrated into CMMS Toolset. Requested by Trac WSMR, AF/ASCET.

Other Information About the Tool (references describing it, methods/metrics employed, any special relationship between this tool and CASE tools or other software development/testing automation, etc.) – use end note for material that causes the disclaimer to move to the next page:

- operates on: Oracle, IBM OB-2, Ingress, Sybase, Informix, and other ODBC compliant DB systems.
- operates on: ASCII fixed length files, other ASCII file formats such as comma-separated variable formations and dBase, FoxPro, and Paradox.
- User defines roles and can either change his/her copy of the data or send a system-generated report to the data owner (or both).

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SIMVAL 99 M&S V&V Tool Survey Form (To be submitted with a Participation Request form)

This form is designed to collect information about M&S V&V automation capabilities. The information obtained by responses to this survey will be provided to all participants in SIMVAL 99. Those who provide information via this form will be provided an opportunity to have additional information about their tools available for SIMVAL 99 participants (as described in the note at the end of this form). ***Restrict response to fit on form.***

Tool Name: Evaluation Environment™

Developer/Provider/POC [name & contact information of individual(s) and/or organization]:

Orca Computer, Inc.
Virginia Tech Corporate Research Center
1800 Kraft Drive, Suite 111
Blacksburg, VA 24060-6370

Dr. Osman Balci, President
E-mail: Balci@OrcaComputer.com
Tel: 540-961-ORCA (6722)
Fax: 540-961-4162
URL: <http://www.OrcaComputer.com>

Brief description of primary use(s) for the tool & what issues it is intended to address:

Evaluation Environment™ is a general purpose software tool that enables qualitative and quantitative evaluation by using a hierarchy of indicators; subject matter experts; analytic hierarchy process; crisp, fuzzy and nominal scores; rule-based object-oriented knowledge specification; HTML-based reports; and graphical representation of evaluation results.

Evaluation Environment™ is intended to address many issues including:

- Accreditation and Quality Assessment of M&S applications
- M&S Data Quality Assessment and Certification
- Government Test and Evaluation, and Certification
- Complex System Design Quality Assessment
- Software Quality Assessment

Simulation Phases For Which the Tool Is Applicable (please check all which apply):

<input type="checkbox"/> M&S Planning (include resource estimation)	<input type="checkbox"/> M&S Configuration Management
<input type="checkbox"/> M&S Requirements	<input type="checkbox"/> M&S Use/Application & Maintenance
<input type="checkbox"/> M&S Conceptual Modeling	<input checked="" type="checkbox"/> M&S Assessment/Evaluation
<input type="checkbox"/> M&S Design	<input type="checkbox"/> M&S Interoperability/Compatibility
<input type="checkbox"/> M&S Implementation	<input type="checkbox"/> M&S Modification
<input checked="" type="checkbox"/> M&S Testing & Integration	<input checked="" type="checkbox"/> V&V Planning (include resource estimation)
<input checked="" type="checkbox"/> Unit	<input checked="" type="checkbox"/> V&V Documentation/Reporting
<input checked="" type="checkbox"/> Function	<input checked="" type="checkbox"/> V&V Management
<input checked="" type="checkbox"/> Sub-system	<input checked="" type="checkbox"/> Accreditation/Certification
<input checked="" type="checkbox"/> System	<input checked="" type="checkbox"/> Standards Compliance
	<input checked="" type="checkbox"/> Other (specify): See above list.

Simulation Environments For Which the Tool Is Applicable (please check all which apply):

Evaluation Environment™ is intended for the quality assessment of any type of modeling and simulation.

Simulation Variety:

- Closed Form
- Continuous
- Discrete Event
- Real-Time

- Human/System/Hardware-in-loop
- Distributed processing
- Distributed simulation
- Other (specify):

Development Environment:

- Structured
- Object-oriented
- Formal system
- "Water Fall"

Evolutionary/Spiral
 Rapid Prototyping
 Other (specify):
Software Language(s) Which the Tool Accommodates

SIMVAL 99 M&S V&V Tool Survey Form (page 2) for Tool Name (Evaluation Environment™)

Simulation Aspects For Which the Tool Is Applicable (please check all which apply):

- Architecture
- Data
- Collection
- Reduction
- System/Component Interfaces
- Human Interfaces (e. g., GUIs)

- Algorithms
- Behaviors
- Prototypes
- Management
- Test Planning/Execution
- Results Evaluation
- Other (specify): VV&A and VV&C

Tool Use Considerations: What special equipment (host computer, operating system, network, configuration, etc.)/application software/facilities/skills are required for effective use of the tool?

- Windows 95, Windows 98, and Windows NT 4.0 operating systems
- State-of-the-art graphical user interface
- Easy to use

What training is required (length and where available) for personnel using the tool?

Minimum or no training is required depending on the user's computer skills.

What is the cost of the tool?

- Commercial Single User License† \$2,995
- Government Single User License† \$1,495
- University Single User License† \$1,495
- Site license is negotiable.

† Half price for each additional user license.

What M&S or kinds of M&S have used this tool previously?

BMDO NMD Project and BMDO V&V WIPT

Other Information About the Tool (references describing it, methods/metrics employed, any special relationship between this tool and CASE tools or other software development/testing automation, etc.):

A repository of hierarchies of indicators are under development for areas such as accreditation of M&S applications, software quality assessment, and M&S V&V status characterization. Contact the company for other hierarchies and more information.

Table space (about 3 ft x 2 ft) will be provided without charge in the SIMVAL 99 break & mixer area for additional descriptive materials and/or display about a tool – this area can also be manned by a representative of the tool in the afternoon of Day 1 of SIMVAL 99 (January 26th). Those who avail themselves of this opportunity must be registered for either full or limited participation in SIMVAL 99. The number who can be accommodated in this fashion is limited and will be allocated on a first-request basis (indicated on SIMVAL 99 participation application).

SIMVAL 99 M&S V&V Tool Survey Form

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Tool Name: JWARS V&V Database

Developer/Provider/POC [name & contact information of individual(s) and/or organization]:

Jack Jordan
BMH Associates
5425 Robin Hood Road, Suite 201
Norfolk, VA 23513-2441

Brief description of primary use(s) for the tool & what issues it is intended to address:

Tool directly supports correlation of Derived Representation Requirements (DRR) and Model Validation Requirements (MVR) to Unified Joint Task List measures and to Joint Application Design (JAD) packets and the Operational Requirements Document (ORD)

Simulation Phases For Which the Tool Is Applicable (please check all which apply):

M&S Planning (include resource estimation)
 M&S Requirements
 M&S Conceptual Modeling
 M&S Design
 M&S Implementation
 M&S Testing & Integration
 Unit
 Function
 Sub-system
 System

M&S Configuration Management
 M&S Use/Application & Maintenance
 M&S Assessment/Evaluation
 M&S Interoperability/Compatibility
 M&S Modification
 V&V Planning (include resource estimation)
 V&V Documentation/Reporting
 V&V Management
 Accreditation/Certification
 Standards Compliance
 Other (specify):

Simulation Environments For Which the Tool Is Applicable (please check all which apply):

Simulation Variety:

Closed Form
 Continuous
 Discrete Event
 Real-Time
 Human/System/Hardware-in-loop
 Distributed processing
 Distributed simulation
 Other (specify):

Development Environment:

Structured
 Object-oriented
 Formal system
 "Water Fall"
 Evolutionary/Spiral
 Rapid Prototyping
 Other (specify):

Software Language(s) Which the Tool Accommodates: Microsoft Access 97

Please continue as appropriate (use end note for material beyond this page).

SIMVAL 99 M&S V&V Tool Survey Form (page 2) for (Tool Name):

Simulation Aspects For Which the Tool Is Applicable (please check all which apply):

<input type="checkbox"/> Architecture	<input checked="" type="checkbox"/> Algorithms
<input type="checkbox"/> Data	<input type="checkbox"/> Behaviors
<input type="checkbox"/> Collection	<input type="checkbox"/> Prototypes
<input type="checkbox"/> Reduction	<input checked="" type="checkbox"/> Management
<input type="checkbox"/> System/Component Interfaces	<input checked="" type="checkbox"/> Test Planning/Execution
<input type="checkbox"/> Human Interfaces (e. g., GUIs)	<input checked="" type="checkbox"/> Results Evaluation
	<input type="checkbox"/> Other (specify)

Tool Use Considerations: What special equipment (host computer, operating system, network, configuration, etc.)/application software/facilities/skills are required for effective use of the tool?

Microsoft Access 97, Internet connectivity for database replication and synchronization. Also requires Microsoft Application Manager for Internet synchronization.

What training is required (length and where available) for personnel using the tool?

None - very easy to use.

What is the cost of the tool?

MS Access 97 - \$339 MS Office Developer Edition - \$799.

What M&S or kinds of M&S have used this tool previously? None

Other Information About the Tool (references describing it, methods/metrics employed, any special relationship between this tool and CASE tools or other software development/testing automation, etc.) – use end note for material that causes the disclaimer to move to the next page:

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SIMVAL 99 M&S V&V Tool Survey Form

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Tool Name: McCabe Visual Testing Toolset

Developer/Provider/POC [name & contact information of individual(s) and/or organization]:

Pete Christensen - MITRE
Gray Rosse - McCabe & Assoc.

Brief description of primary use(s) for the tool & what issues it is intended to address:

- Complex Test Analysis
- Unit Test
- Code Coverage
- Verification
- Validation

Simulation Phases For Which the Tool Is Applicable (please check all which apply):

<input type="checkbox"/> M&S Planning (include resource estimation)	<input type="checkbox"/> M&S Configuration Management
<input type="checkbox"/> M&S Requirements	<input checked="" type="checkbox"/> M&S Use/Application & Maintenance
<input type="checkbox"/> M&S Conceptual Modeling	<input checked="" type="checkbox"/> M&S Assessment/Evaluation
<input type="checkbox"/> M&S Design	<input type="checkbox"/> M&S Interoperability/Compatibility
<input checked="" type="checkbox"/> M&S Implementation	<input checked="" type="checkbox"/> M&S Modification
<input checked="" type="checkbox"/> M&S Testing & Integration	<input type="checkbox"/> V&V Planning (include resource estimation)
<input type="checkbox"/> Unit	<input checked="" type="checkbox"/> V&V Documentation/Reporting
<input type="checkbox"/> Function	<input checked="" type="checkbox"/> V&V Management
<input type="checkbox"/> Sub-system	<input type="checkbox"/> Accreditation/Certification
<input type="checkbox"/> System	<input type="checkbox"/> Standards Compliance
	<input type="checkbox"/> Other (specify):

Simulation Environments For Which the Tool Is Applicable (please check all which apply):

Simulation Variety:

- Closed Form
- Continuous
- Discrete Event
- Real-Time
- Human/System/Hardware-in-loop
- Distributed processing
- Distributed simulation
- Other (specify):

Development Environment:

- Structured
- Object-oriented
- Formal system
- "Water Fall"
- Evolutionary/Spiral
- Rapid Prototyping
- Other (specify):

Software Language(s) Which the Tool

Accommodates: C, C++, ADA, JAVA, Fortran
VB COBOL

Please continue as appropriate (use end note for material beyond this page).

SIMVAL 99 M&S V&V Tool Survey Form (page 2) for (Tool Name):

Simulation Aspects For Which the Tool Is Applicable (please check all which apply):

<input type="checkbox"/> Architecture	<input type="checkbox"/> Algorithms
<input type="checkbox"/> Data	<input type="checkbox"/> Behaviors
<input type="checkbox"/> Collection	<input type="checkbox"/> Prototypes
<input type="checkbox"/> Reduction	<input type="checkbox"/> Management
<input type="checkbox"/> System/Component Interfaces	<input checked="" type="checkbox"/> Test Planning/Execution
<input type="checkbox"/> Human Interfaces (e. g., GUIs)	<input type="checkbox"/> Results Evaluation
	<input type="checkbox"/> Other (specify)

Tool Use Considerations: What special equipment (host computer, operating system, network, configuration, etc.)/application software/facilities/skills are required for effective use of the tool?

PC or Unix Workstation

What training is required (length and where available) for personnel using the tool?

On-site or in-plant. One day install ? (ramp-up)
Three-day structured test class

What is the cost of the tool? N/A

What M&S or kinds of M&S have used this tool previously?

Navy, USMC, Army, Air Force, DoD / Command, Control, Weapons Systems

Other Information About the Tool (references describing it, methods/metrics employed, any special relationship between this tool and CASE tools or other software development/testing automation, etc.) – use end note for material that causes the disclaimer to move to the next page:

- Work with GUI Test Tools
- Work with Configuration Management Tools

Disclaimer of Endorsement: Reference in SIMVAL 99 materials to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not constitute or imply its endorsement, recommendation, or favoring by the United States Government, by MORS, or by any other organization or person.

SIMVAL 99 M&S V&V Tool Survey Form

This form is designed to collect information about M&S V&V automation capabilities. The information obtained by responses to this survey will be provided to all participants in SIMVAL 99. Those who provide information via this form will be provided an opportunity to have additional information about their tools available for SIMVAL 99 participants (as described in the note at the end of this form). *Restrict response to fit on form.*

Tool Name: PerfMETRICS

Developer/Provider/POC [name & contact information of individual(s) and/or organization]:

David B. Cavitt, Edward P. Harvey
BMH Associates, Inc.
5424 Robin Hood Rd., Suite 201
Norfolk, VA 23513-2441

Brief description of primary use(s) for the tool & what issues it is intended to address:

PerfMEDTRICS is a performance monitoring application that captures run-time performance data on distributed simulations (and others). It provides meaningful and relevant information for decision-makers assessing the impact of run-time performance on the validity of simulation behavior. Data collection relates to model, simulation infrastructure, and operating systems performance.

Simulation Phases For Which the Tool Is Applicable (please check all which apply):

M&S Planning (include resource estimation)
 M&S Requirements
 M&S Conceptual Modeling
 M&S Design
 M&S Implementation
 M&S Testing & Integration
 Unit
 Function
 Sub-system
 System

M&S Configuration Management
 M&S Use/Application & Maintenance
 M&S Assessment/Evaluation
 M&S Interoperability/Compatibility
 M&S Modification
 V&V Planning (include resource estimation)
 V&V Documentation/Reporting
 V&V Management
 Accreditation/Certification
 Standards Compliance
 Other (specify):

Simulation Environments For Which the Tool Is Applicable (please check all which apply):

Simulation Variety:

Closed Form
 Continuous
 Discrete Event
 Real-Time
 Human/System/Hardware-in-loop
 Distributed processing
 Distributed simulation
 Other (specify):

Development Environment:

Structured
 Object-oriented
 Formal system
 "Water Fall"
 Evolutionary/Spiral
 Rapid Prototyping
 Other (specify):

Software Language(s) Which the Tool

Accommodates: Software Language(s) which the tool accommodates: C, Motif, C++

Please continue as appropriate (use end note for material beyond this page).

SIMVAL 99 M&S V&V Tool Survey Form (page 2) for (Tool Name):

Simulation Aspects For Which the Tool Is Applicable (please check all which apply):

<input type="checkbox"/> Architecture	<input checked="" type="checkbox"/> Algorithms
<input checked="" type="checkbox"/> Data	<input checked="" type="checkbox"/> Behaviors
<input checked="" type="checkbox"/> Collection	<input checked="" type="checkbox"/> Prototypes
<input type="checkbox"/> Reduction	<input checked="" type="checkbox"/> Management
<input checked="" type="checkbox"/> System/Component Interfaces	<input checked="" type="checkbox"/> Test Planning/Execution
<input type="checkbox"/> Human Interfaces (e. g., GUIs)	<input checked="" type="checkbox"/> Results Evaluation
	<input type="checkbox"/> Other (specify)

Tool Use Considerations: What special equipment (host computer, operating system, network, configuration, etc.)/application software/facilities/skills are required for effective use of the tool?

Currently runs on SGI and Linux-based platforms. Uses Motif. Requires multicast support. Requires application/simulation knowledge in order to insert instrumentation code.

What training is required (length and where available) for personnel using the tool?

Requires integration of application specific performance information with underlying communications infrastructure. Requires modification to existing display interface (GUI) to show relevant performance data.

What is the cost of the tool?

What M&S or kinds of M&S have used this tool previously?

DARPA STOW Tier 3 training environment, Air Force Distributed Training (DMT) with virtual cockpit simulators, Navy Air Traffic Control training environment.

Other Information About the Tool (references describing it, methods/metrics employed, any special relationship between this tool and CASE tools or other software development/testing automation, etc.) – use end note for material that causes the disclaimer to move to the next page:

- [1] Cavitt, D.B., C.M. Overstreet, and K.J. Maly. 1997. A Performance Monitoring Application for Distributed Interactive Simulation (DIS). In Proc. 1997 Winter Simulation Conference, Dec. 1997, 421-428. Assn. for Computing Machinery, NY, NY.
- [2] Cavitt, D.B., J. Bell, M. Checchio, C.M. Overstreet, and K.J. Maly. 1998. Performance Monitoring for the Design, Configurations, and Control of DIS/HLA Exercises. In Proc. 1998 Spring Simulation Interoperability Workshop. 98S-SIW-066.
- [3] Cavitt, D.B., M.A. Gibson, E.P. Harvey, 1998. HLA/STOW Interface Development to Support Distributed Mission Training (DMT). In Proc. 1998 Fall Simulation Interoperability Workshop, 98S-SIW-204.

Disclaimer of Endorsement: Reference in SIMVAL 99 materials to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not constitute or imply its endorsement, recommendation, or favoring by the United States Government, by MORS, or by any other organization or person.

Appendix D SIMVAL 99 Presentations

This appendix contains pointers to SIMVAL 99 briefings and presentations contained in the SIMVAL 99 Annex. These consists of the three presentations of the opening keynote plenary session on Tuesday morning, briefings made to SIMVAL 99 working groups, and the formal outbriefs by the three working groups and the synthesis group in the final plenary session on Thursday afternoon. These unannotated briefing materials supplement information contained in the body of the SIMVAL 99 report.

D1 — Plenary Keynote Session Presentations by CAPT McBride, Col Konwin, and Dr. Davis

Additional biographical material may be found about the scheduled speakers for the keynote session at the end of the SIMVAL TOR in Appendix A.

CAPT Dennis McBride USN (Program Officer, Medical S&T, Office of Naval Research) challenged SIMVAL 99 participants to think boldly about future modeling and simulation (M&S) as well as about verification and validation (V&V) technology in his keynote address, "The Future of Technology and VV&A in Warfighting Simulation." CAPT McBride stressed the two vectors of computational capabilities and trends (including those from bioinformatics) and of warfighting means and methods as foci for the VV&A community. He emphasized the problems associated with the rapid rates of change in both of these vectors and their implications for the VV&A community. CAPT McBride supplemented his slides with excerpts from a video program aired as part of a Public Broadcasting System (PBS) documentary on Karl Sims' work on Artificial Evolution.

Col Kenneth Konwin USAF (Director, Defense Modeling and Simulation Office) was a surrogate speaker in the plenary session. The speaker originally scheduled, Mr. Robert Poston of Aonix, had a family medical emergency that precluded his attendance. Col Konwin's briefing on "V&V Technology Review" gave a high level overview of V&V technology, and correlated those ideas with comments about personnel talent (a theme that cropped up more than expected in all parts of the SIMVAL 99 Workshop), techniques, and tools.

Dr. Paul Davis (RAND and the RAND Graduate School) offered a cautionary perspective on VV&A, noting issues of research base, bureaucratic mischief that impedes high-quality analysis, and opposing trends in commercial off-the-shelf software, some of which help and some of which hurt the cause of VV&A. His presentation, "Beyond Box Checking: How Can Technology Help Model Building and VV&A?" suggested principles for VV&A related tools, illustrating some of the points with examples from recent work.

D2 — Briefings to SIMVAL 99 Working Groups

Because SIMVAL 99 was workshop and not a conference, there were relatively few briefings at it. Briefings were used in the working groups to help group participants to understand issues and topics so that they could better focus their discussions. While the material presented in this section is substantially the same as what was presented to the working groups, there have been a few corrections and modifications. In a few cases, materials shown to a working group were not available for this report.

Briefings in WG1 (Verification Technology)

- D-WG1-1 "M&S Verification Technology: An Overview" by Osman Balci: to identify the issues and problems to be addressed during the workshop (this material is based upon the Balci paper which was part of the SIMVAL 99 Handout and which is included in Appendix F; for that reason it is not included)
- D-WG1-2 "M&S Requirements Verification" by Gary Kollmorgen
- D-WG1-3 "M&S Requirements Verification" by Randy Michelsen
- D-WG1-4 "M&S Conceptual Model Verification" by Furman Haddix
- D-WG1-5 "M&S Design Verification" by Delores R. Wallace
- D-WG1-6 "M&S Implementation Verification" by Richard E. Nance

- D-WG1-7 "Overview of Six Major VV&A Processes and Associated Cost Models" by Robert O. Lewis to a combined session for Working Groups 1 (Verification Technology) and 3 (VV&A Costs)

Briefings in WG2 (Validation Methodology & Technology)

- D-WG2-1 "Modular Semi-Automated Forces (ModSAF) Experimentation (VV&A, Physical Models, Data)" by John Thomas
- D-WG2-2 "A Construct for the Use of SMEs" by Scott Harmon

Briefings in WG3 (Technology Impact on VV&A Costs)

- D-WG3-1 "Costing Of Model And Simulation (M&S) Verification, Validation, And Accreditation (VV&A) Within DoD -- A Managed (Marginal) Investment Strategy" by Robert Gravitz and Bill Waite
- D-WG3-2 (same as WG1-7) "Overview of Six Major VV&A Processes and Associated Cost Models" by Robert O. Lewis to a combined session for Working Groups 1 (Verification Technology) and 3 (VV&A Costs)
- D-WG3-2 "Advanced Distributed Simulation (ADS) Work Breakdown Structure (WBS) AS of 13 Jan 1999" by LTC Cannon

D3 -- Thursday Afternoon Outbriefs

On Thursday afternoon, leadership of the SIMVAL Working Groups and Synthesis Group briefed their findings, issues, and recommendations to SIMVAL 99 participants in a closing plenary session. The outbriefs contained in this report are polished and expanded versions of the Thursday afternoon outbriefs and were provided by the group leaders. The body of this report contains findings, issues, and recommendations for the SIMVAL 99 Workshop as a whole. Conclusions for the Workshop as a whole are not just a summation of the findings, issues, and recommendations from the Working Groups and Synthesis Group. In some cases, ideas from a single working group were not seen as compelling by the rest of the SIMVAL 99 leadership and did not become part of the Workshop's conclusions. Inclusion of the Thursday afternoon outbriefs in this appendix of the SIMVAL 99 report is a method of documenting the diversity of ideas addressed in the Workshop.

- **Working Group 1: Two Outbriefs** (one by Dr. Balci, the other by Mr. Lewis)
- **Working Group 2**
- **Working Group 3**
- **Synthesis Group**
- **SIMVAL 99 Co-Chairs**

Appendix E Acronyms

ADS	Advance Distributed Simulation
AI	Artificial Intelligence
APL	Applied Physics Laboratory (of Johns Hopkins University)
A2ATD	Advanced Armor Advanced Technology Demonstration
CASE	Computer Aided Software Engineering
CER	Cost Estimating Relationship
CM	Conceptual Model
CMM	Capability Maturity Model
CMMS	Conceptual Models Of The Mission Space
COTS	Commercial Off-The-Shelf
DARPA	Defense Advanced Research Projects Agency
DB	Database
DMSO	Defense Modeling and Simulation Office
DoD	Department of Defense
DTIC	Defense Technical Information Center
FFRDC	Federally Funded Research and Development Center
GOTS	Government Off-The-Shelf
HTL	Human In The Loop
IDE	Integrated Development Environment
ISO	International Standards Organization
JADS JT&E	Joint Advanced Distributed Simulation Joint Test & Evaluation
JADS JTF	Joint Advanced Distributed Simulation Joint Test Force
JE	Joint Experimentation
JHU/APL	Johns Hopkins University Applied Physics Laboratory
KA	Knowledge Elucidation / Acquisition
KE	Knowledge Engineering
KDD	Knowledge Discovery In Databases
MEL	Master Environmental Library
ModSAF	Modular Semi-Automated Forces
MORS	Military Operations Research Society
MSIAC	M&S Information Analysis Center
MSOSA	M&S Operational Support Activity
MSRR	Modeling and Simulation Resource Repository
M&S	Modeling and Simulation
NSF	National Science Foundation
ONR	Office of Naval Research
OOP	Object Oriented Paradigm
PM	Program Manager
QA	Quality Assurance
RFP	Request For Proposal
RPG	(DMSO) Recommended Practices Guide (for VV&A)
R&D	Research & Development
S&T	Science And Technology
SBA	Simulation-Based Acquisition
SCSI	Society for Computer Simulation International
SEDRIS	Synthetic Environment Data Representation & Interchange Specification
SEE	Software Engineering Environment
SEI	Software Engineering Institute
SIMVAL	Simulation Validation

SME	Subject Matter Experts
SOW	Statement Of Work
SQA	Software Quality Assurance
STOW	Synthetic Theater of War
UARC	University Affiliated Research Center
UML	Unified Modeling Language
UUT	Unit Under Test
V&V	Verification And Validation
VV&A	Verification, Validation and Accreditation
4GL	Fourth Generation Language

Appendix F

Read-Ahead Package and Handout Items

This appendix contains the entire read-ahead package and an item from the SIMVAL 99 handout materials: a paper by Osman Balci, "Verification, Validation, and Accreditation," [*Proceedings of the 1998 Winter Simulation Conference* (eds. D. J. Medeiros, E. F. Watson, J. S. Carson, and M. S. Manivannan), pp. 41-48] which has a table identifying functional applicability of V&V techniques.

Read-Ahead Package

Military Operations Research Society (MORS) Simulation Validation (SIMVAL) Workshop 99

Making VV&A Effective AND Affordable

26-29 JANUARY 1999 at JHU/APL Kossiakoff Conference Center (Laurel, Maryland, USA)
SIMVAL 99 is co-sponsored by the Society for Computer Simulation International (SCSI)

This read-ahead package is primarily identifies resources which should be of special interest to participants in SIMVAL 99. All prospective participants are encouraged to explore these resources prior to SIMVAL 99 so that they can contribute most significantly to accomplishment of SIMVAL 99 objectives.

As stated in the SIMVAL 99 Terms of Reference (TOR):

- SIMVAL 99 will explore how to ensure M&S correctness and credibility in effective, efficient, and affordable ways.
- It will examine current *technology* supporting VV&A and identify promising areas of possible technology developments that can enhance VV&A. Such enhancements may be achieved by making VV&A more effective for a given level of resources or by allowing the same level of VV&A to be achieved with reduced resources.
- The workshop will focus on:
 - 1) verification technology,
 - 2) validation technology and methodology, and
 - 3) the impact of technology on VV&A costs.
- The emphasis of the SIMVAL 99 Workshop is on VV&A technology, but this emphasis is in the context of making models and simulations more useful and effective in operations research and analysis.
- In addition to insights gained by SIMVAL 99 participants, the primary product of the workshop will be a report of the state-of-the-art in simulation VV&A technology and methodology. Current issues, concerns, and recommendations will be identified. Presentations of this information are expected at the MORS 1999 symposium and at appropriate SCSI conferences.

The materials in this read-ahead package are organized into four sections:

- 1) Computer-Aided Verification Tools,
- 2) Tools for the Validation & Verification of Knowledge-Based Systems,
- 3) Orientation to Formal Methods, their Costs-Benefit, Associated Automation, and
- 4) Suggested General Reading about VV&A.

1. Computer-Aided Verification Tools

The information in this section came from the URL below:
<http://www-cad.eecs.berkeley.edu/~tah/CAV/tools.html>

It was prepared by Tom Henzinger and last updated in April, 1997, by tah@eecs.berkeley.edu.

The following tools were demonstrated at CAV 96 or CAV 97.

CADP (Caesar-Aldebaran Distribution Package): a protocol validation and verification toolset

The Concurrency Factory: a graphical environment for specification, simulation, verification, and implementation of concurrent systems

Fc2Tools and Auto/Graph: a symbolic/explicit verification toolset for concurrent processes

HyTech: a symbolic model checker for embedded systems

Invariant Checker: automated deductive verification of reactive systems

Kronos: formal verification of real-time systems based on timed automata and temporal logic

MDG (Multiway Decision Graphs): abstract state enumeration for RTL functional verification

METAFrame: tool integration and engineering environment for the organization and synthesis of large-grain software systems

MoSeL: a decision procedure for monadic second-order logic over finite strings

Mu-cke: a model checker

Murphi: finite-state verification of high-level concurrent systems, such as protocols, synchronization algorithms and memory-model specifications

NP-Tools: general-purpose verification toolbox offering propositional and integer arithmetic theorem-proving capability

PARAGON: a tool for visual specification and verification of distributed real-time systems

Partial-order Package: an extension of SPIN

PEP (Programming Environment based on Petri nets): modeling, simulation, analysis, and verification of parallel systems

PNN (Product Net Machine) & SH-Verification Tool: a specification and verification tool for cooperating systems

PROD: a Pr/T-net reachability analysis tool that supports verification with partial-order reductions

PVS: a verification system

RTGIL (Real-Time Graphical Interval Logic) **Tools**: graphical editor, satisfiability checker, counterexample generator, database and proof manager for concurrent real-time systems

SMC: symmetry-based model checker for verification under fairness assumptions

SPIN: an efficient LTL model checker for distributed software designs

STeP (The Stanford Temporal Prover): verification of reactive and real-time systems

TermiLog: a system for checking the termination of queries to logic programs

Uppaal: validation and verification tools for real-time systems

VeriSoft: automatic detection of coordination problems between concurrent processes executing arbitrary (e.g., C or C++) code

VIS: a system for verification and synthesis

Note: More verification tools can be found at the Oxford Formal Methods home page.

2. Tools for the Validation & Verification of Knowledge-Based Systems

The information in this section came from the URL below:

<http://www.cs.abdn.ac.uk/~apreece/Research/vvtools.html>

The focus is on 1985-1995 references. The information was compiled by Robert T. Plant
(Department of Computer Information Systems, University of Miami, Coral Gables, FL)

An Annotated Bibliography on Validation & Verification of KBS is also available.
<http://www.cs.abdn.ac.uk/~apreece/Research/vvbiblio.html>

CHECKER

X. Yu & Biswas

"CHECKER: An Efficient Algorithm for Knowledge-Based System Verification"
In, Proc. of the Third International Conference on Engineering Applications of A.I.
IEA/AIE-90. 1990

CLINT

L. de RAEDT, G. SABLON & BRUYNOOGHE

"Using Interactive Concept Learning for Knowledge-Base Validation & Verification and test of KBS"
Chapter 12,
pp 177-190, John Wiley & Sons, Chichester, England, 1991.

COCO

Stephane Loiseau

"A Method for Checking and Restoring the Consistency of Rule bases"
Int. J. of Human-Computer Studies (1994) 40, 425-442

CONKRET

Beatriz Lopez

"CONKRET: A Control Knowledge Refinement Tool"
In, Validation, Verification and Test of Knowledge-based Systems, pp 191-206
Edited by: Marc Ayel & Jean-Pierre Laurent
Wiley

COVADIS

M.C. Rousset

"On the consistency of Knowledge-bases: the COVADIS system"

In proceedings of the ECA188 Conference pp 79-84, Mancher,
Germany 1988

COVER/VERITE

Alun Preece, Rajjan Shinghal, Aida Batarekh,

"Principles and Practice in Verifying Rule-Based Systems",

Knowledge Engineering Review, Vol. 7, No. 2, 1992. pp115-141.

CRSV-CLIPS

C.Culbert & R.Savely

"Expert system verifications & Validation"

Proc. of First AAAI Workshop on V,V & Testing. Palo Alto, CA
August 1988.

DERIVATION TOOL

G.-C. Roman, R.F. Gamble, and W.E., Ball.

"Formal Derivation of Rule-Based Programs",

IEEE Transations on Software Engineering, Vol. 19, No. 3, p. 277-296, March 1993.

EFG TRANSLATOR

L.A. Becker, P.G. Green & J. Bhutinager

"Evidence Flow Graphs for V&V of Expert Systems", NASA Contractor Report 181810

ESC

Brian Cragun, Harold Steudel,

"A Decision Table Based Processor for Checking Completeness and Consistency"

International Journal of Man Machine Studies, No. 26, 1987, pp633-648.

EVA

R.A. Stachowitz, C.L. Chang, T.S. Stock, & J.B. Coombs

"Building Validation Tools for Knowledge-based Systems"

First Annual Workshop on Space Operations Automation and Robotics (SOAR '87)

Houston, Texas. August 5-7, 1987, pp209-216

FEAT

S.W. French, C. Culbert, D. Hamilton

"Experiences in improving the state of Practice in Verification and Validation of Knowledge- Based Systems"

Workshop Notes, 6th Annual Workshop on V&V: AAAI 1994, Washington D.C., pp86-93.

FFAAK

T.V. Cuda & C.P. Dolan
"Tool Aided Non Formal Knowledge Verification", Workshop Notes: AAAI Workshop on V&V,
Anaheim.1991.

IMVER

F. Coener, T.Berch-Capon, A.Kent
"A Binary Encoded Incidence Matrix Representation to Support KBS Verification"
In: Working Notes 7 Workshop on V&V of KBS at AAAI 94---pp84-93.

IRS-CBR

T. Terano & K.Kobayashi
"Changing the Traces: Refining a rule-base by Genetic Algorithms"
IJCAI Workshop on V&V of Knowledge-based Systems Notes 1995, Montreal, Canada,
August 19th 1995.

KB-REDUCER3

K.Williamson & M.Dahl
"Knowledge- based reduction for verifying Rule Bases Containg Equations"
In: Working Notes: 6 Workshop on V.V of KBS at AAAI, Washington, D.C., pp 66-71
A. Ginsberg & L.Rose
"KB-Reducer: A System that Checks for Inconsistency and Redundancy in Knowledge-bases",
Technical Report, AT&T Labs, 1987

KRFOCL

Michael J. Pazzani
"A Set Covering Approach to Testing rule-based expert systems"
Workshop Notes AAAI 1990
Boston, MA

KRUST

S: CRAW
"Automating the refinement of knowledge-Based Systems"
Ph. D. Dissertation, University of Aberdeen, Scotland. 1991

KVAT

O.J. Mengshoel
"A tool for incremental K.Validation in a K.Engineering Workberch"
Proc. of the European Workshop on the verification & validation
of KBS, EUROVAN 91. Cambridge England, July 1991 pp 133-146

MELODIA

E. Charles, & O.Dubois
"MELODIA: Logical Methods for Checking K-Bases"
In: M.Ayel & J.P. Laurant (Eds): "Validation , Verification and Test of Knowledge-Based
Systems" Chapter 7, pp95-105, Wiley & Sons, Chichester England 1991

MVP-CA

M. Mehrotra, C.Wild
"Multi-Viewpoint Clustering Analysis"
In: Working Notes: 6 Workshop on Verification and Validation of KBS
at AAAI Washington, D.C., pp 52-63

PATH-HUNTER and PATH-TRACER

A.D.Precce, C.Grossner, P.G.Chander, T.Radhakrishnan
"Structural validation of Expert systems using a formal Model"
In: Working Notes: Workshop on V&V of KBS at
AAAI 93, Washington D.C. August 1993, pp 19-26

PREPARE

D. Zhang & D. Nguyen
"PREPARE: A Tool for Knowledge-base Verification"
IEEE Transactions on Knowledge and Data Engineering , Vol. 6, No. 6. December 1994, pp983-989

PROLOGA

J. Vanthienen
"Knowledge Acquisition and Validation Using a Decision Table Engineering Workbench"
World Congress of Expert Systems 1991, pp1861-1868

RITCaG

U.C. Gupta & J.BIEGEL
"RITCaG: A Rule-Based Intelligent Test Case Generator"
In, Working Notes, AAAI Workshop on KBS, Verification,
Validation and Testing: July 1990, Boston MA.

SACCO/SYCOJET

Marc Ayel & Jean Pierre Laurent
"SACCO-SYCOJET: Two Different Ways of Verifying Knowledge-Based Systems"
In, Validation, Verification and Test of Knowledge-based Systems, pp 62-76
Edited by: Marc Ayel & Jean-Pierre Laurent
Wiley

SAVES

S.Smith & A.Kandel
Verification and Validation of Rule-based Expert Systems
CRC Press

SOCRATES

B.Traylor, U.Schwuttke, A.Quan
"A Tool for American verification of real-Time Expert systems"
In: Working Notes 7 Workshop on V&V of KBS at AAAI 94,
Seattle, WA, August 1994, pp 79-83

SPT

R. Phelps, W. Aerts

"Improving Validation and Verification of Knowledge-Based Systems Through Naturally Comprehensible Flow representations"

In: EVROAV '93, Proceedings of the European Symposium on the Validation and Verification of Knowledge-Based Systems, Eds: J. Cardenosa, & P. Meseguer, pp 295-309

SYSIFE

P. Mazas

"Designing Knowledge Validation Through Experimentation: The SYSIFE System"

In: M. Ayel & J.P. Laurent (Editors), Validation, Verification and Test of Knowledge-based Systems, pp 119-145. Wiley 1991

TRUBAC

V. Barr

"Rule-Based Coverage Measures Applied to Testing Rule-Bases with Uncertainty"

IJCAI Workshop on V&V of Knowledge-based Systems Notes 1995, Montreal, Canada,

August 19th 1995.

VALID

J. Cardevosa, N. Juusto

"General Overview of the VALID Project"

In: EVROAV '93, Proceedings of the European Symposium on the Validation and Verification of Knowledge-Based Systems, Eds: J. Cardenosa, & P. Meseguer, pp53-67

VALIDATOR

Y.Kang & T.Bahill

"A Tool for Detecting Expert System Errors"

AI Expert, Feb. 1990 pp42-51

VASTT

M.Steib, R.Small, C.Castells-Schofield.

"Tailoring VASTT for Expert system verification, validation and testing"

Workshop Notes, AAAI Workshop on V & V , 1991.

VITAL

Alain Rouge, Jean Yves Lapicque, Florent Brossier, Yves Lozinguez

"Validation and verification of KADS Data & Domain Knowledge"

EUROAV '93, pp69-83

Palma De Mallorca, Spain 24-26th March 1993

Univ. Polit. de Madrid (UPM)

VVR

N. Zlatarova

"VVR: A Uniform Framework for Expert System Knowledge Bases Verification, Validation and Refinement"

Workshop Notes: AAAI Workshop on V&V, Anaheim 1991.

WRAPPINGS

K.L. Bellman & C. Landauer

"The Modeling Issues Inherent in testing and Evaluating K-Based Systems"

Expert systems with Applications Journal Vol,1, pp 199-215 (1990).

3. Orientation to Formal Methods, their Costs-Benefit, Associated Automation

Orientation to formal methods, their costs-benefit, and associated automation may be found in Volume 1 of NASA-GB-002-95 (Release 1.0), *Formal Methods Specification and Verification Guidebook for Software and Computer Systems*, July 1995, NASA Office of Safety and Mission Assurance. This document itself (as well as its associated Volume 2 which contains more detailed information about formal methods) can be downloaded from a NASA website about Formal Methods. The URL of this website is:

http://eis.jpl.nasa.gov/quality/Formal_Methods/index.html . The more general website (drop the "index.html") includes a number of useful links to other websites about formal methods.

4. Suggested General Reading about VV&A

Volume 9 Modeling and Simulation, Technology for the United States Navy and Marine Corps 2000-2035: Becoming a 21st-Century Force, report of the Panel on Modeling and Simulation, Committee on Technology for Future Naval Forces, Naval Studies Board, Commission on Physical Sciences, Mathematics, and Applications, National Research Council. Published by National Academy Press (Washington, DC), 1997.

Robert M. Poston, *Automating Specification-Based Software Testing*, IEEE Computer Society Press, 1996. ISBN: 0-8186-7531-4.

Pertinent contemporary VV&A-related papers and articles may be found in the proceedings of recent Simulation Interoperability Workshops (SIWs) – these can be downloaded from the SIW website (URL = <http://www.sisostds.org/siw/>), in the proceedings of the summer and winter conferences of the Society for Computer Simulation International (SCSI) -- check its website for more information (URL = <http://www.scs.org>), and in the September 1996, March 1997, and June 1997 issues of MORS *PHALANX*.

Some may find the VV&A chapter of the recently published text, *Applied Modeling and Simulation: An Integrated Approach to Development and Operation* (D. J. Cloud & L. B. Rainey, eds, McGraw-Hill, 1998, ISBN: 0-07-228303-3) to be helpful.

Patrick J. Roache, *Verification and Validation in Computational Science and Engineering*, 1998 (ISBN 0-913478-08-3). Available via:
<http://kumo.swcp.com/hermosa/html/books.html>

This book covers modern approaches to Verification and Validation of computer codes and other topics related to the Quantification of Uncertainty and code Quality Assurance. Especially noteworthy are the Method of Manufactured Solutions, a general method for obtaining exact solutions for code Verifications, and the Grid Convergence Index, a method for uniform reporting of grid convergence tests. Applicable to commercial codes and to all problems modeled by partial differential equations, examples include CFD, Groundwater Modeling, etc. Provides useable formulas and practical guidance for error estimation and experimental Validation.

Of possible interest also: William Hankley's *Software Quality: Assurance, Validation, and Verification*, 1998 (see: <http://www.cis.ksu.edu/~hankley>

His notes on vocabulary are interesting:

Validation and verification (V&V) are two specific aspects of the broader area of software quality assurance (SQA). There are different working definitions for V&V.

Boehm [81]: Validation ... does the product have the right functions and features;

Verification .. do the functions work correctly.

IEEE/ANSI: Validation ... the process of evaluating a system or component during or at the end of the development process to determine whether it satisfies specified requirements.
Verification. ..the process of evaluating a system or component to determine whether the products of a given development phase satisfy the conditions imposed at the start of that phase.

E. Kit: Validation .. involves executing the actual software or a simulated mock-up;
it is a "computer-based testing" process;
it usually exposes symptoms of errors.

Verification.. involves evaluating, reviewing, inspecting, and doing desk checks of work products such as requirements, designs, and code (static analysis -- not execution) ;
it is a form of "human" testing.

841: Validation .. any well defined method for checking and or enhancing attributes of quality of software
Verification.. any well defined method for demonstrating or assuring the agreement of descriptions of software attributes.

Note that these definitions are not consistent.

Boehm's definitions do not address issues of "quality" that only indirectly relate to software functions.
For the IEEE definitions, aspects of "quality" can be included as requirements.

Kit's definitions are not appropriate: V & V can both be done manually or using computer tools.

By the 841 definition:

Validation includes testing of software.

Since testing is usually not exhaustive, it is not considered to be a verification of software.

Validation depends upon definitions and measures of quality of software.

Validation also includes aspects of SQA, such as software process plans, reviews, and tools.

Verification covers various forms of "proof of correctness";

such "proof" may be formal (using mathematical models) or informal (using inspections and reviews).

The model-checking method of verification uses exhaustive testing of a model to prove that some property holds.

Some verification may be "weaker" than some validation in that the verification may only prove one small property.

SIMVAL 99 Handout Item: a paper by Osman Balci, "Verification, Validation, and Accreditation"